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Biomass Energy Consumption in the Forest Products Industry

Final Report

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ES. Executive Summary

Approximately 60% of U.S. biomass energy consumption occurs in the forest products industry. The large majority of this consumption is for process heat and steam. The forest products industry produces its own sources of biomass (e.g., bark, sawdust, wood scraps/shavings, wastewater treatment [WWT] sludge), as a by-product of pulp and paper production and wood products manufacturing. The pulp and paper sector of the forest products industry is particularly energy intensive, and the economics of the industry greatly depend on efficient reuse and recycling of chemicals, water, and energy. In its Manufacturing Energy Consumption Survey (MECS) conducted every 4 years, the Energy Information Administration (EIA) only surveys biomass facilities that solely produce process heat and steam as an ancillary fuel. Thus, it is important to understand how changes in the sector during intervening years may affect biomass energy use in the forest products industry.

In the past decade, the value of wood-based biomass as a fuel has increased because of the increase in fossil fuel costs and the promulgation of environmental regulations for industrial boilers, pulp and paper mills, and wood products facilities. For example, mills that might have sold or given away excess bark in the past, are now firing all of the bark in their boilers, because boilers that burn only biomass have lower toxic air emissions than coal-fired boilers, and mills with biomass boilers have more flexibility in how they can dispose of the boiler ash (e.g., they can use land application). In some cases, rising fuel prices and environmental concerns have had offsetting effects. For example, gas turbines purchased only a few years ago (as environmentally friendly energy sources) are now sitting idle at some pulp and paper mills because of increases in the price of natural gas. Concerns about the level and stability of electricity costs in some markets have driven research into the development of gasification technologies at some facilities that will allow them to meet more of their electricity needs, possibly even becoming net suppliers of electricity to the grid. All of these factors, plus changing process and energy technologies, must be considered when estimating potential changes in biomass consumption for the forest products industry. Key findings related to these trends are summarized below.

Key Findings

The report uncovers a number of important developments in technology, economic trends, and public policy that shape the way biomass is currently used and could be used in the future as an energy source in the forest products industry. Several of the most important factors are highlighted here.

1. The U.S. forest products industry is a substantial economic force, both in terms of its role in the U.S. economy and its contribution to world forest products production. The sector's role is changing, however, as U.S. consumers rely more on imports to meet steadily growing

demands. The United States is the world's leading producer and consumer of forest products, accounting for about one-quarter of the world's production and almost 30% of the world's consumption. Almost 1.1 million people are employed in the primary manufacturing activities related to wood products. This employment impact is almost 10 times larger when upstream wood product supplies (forestry and logging) and downstream users of forest products (furniture, construction, and printing) are considered. Output of U.S. wood products, though, has leveled off in recent years, while consumption has continued to grow. As a result, the United States has gone from being a slight net exporter of forest products to a forest products trade deficit of about $13 billion currently (see Figure ES-1). The future use of biomass in the U.S. forest products industry will depend on the degree to which domestic production continues to be displaced by imports and by the specific product composition of the forest products.

2. The U.S. forest products industry is, by far, the largest consumer of biomass for energy consumption (see Figure ES-2). The paper and allied products industry is responsible for 75% of all industrial biomass energy consumption, using over 1,000 trillion British thermal units (Btu). The lumber and wood products industry is a distant second with around 200 trillion Btu.

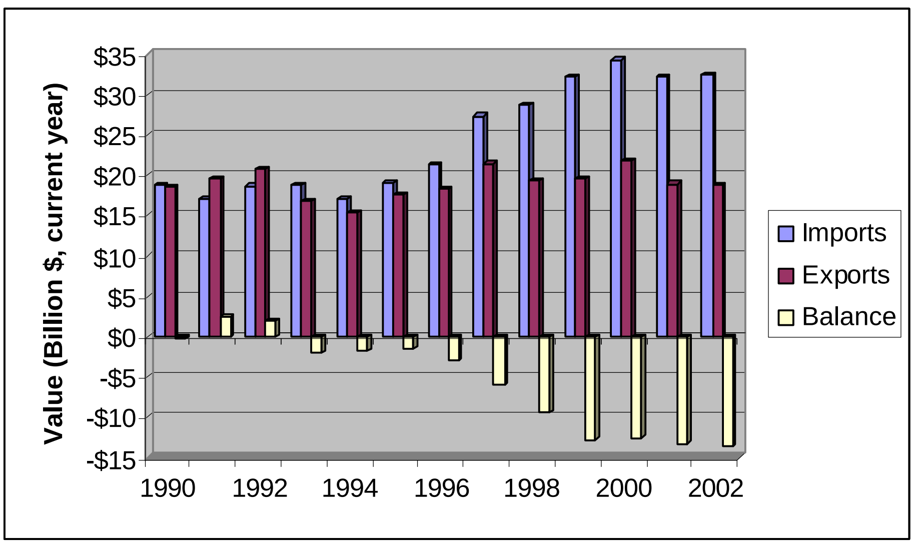

Figure ES-1. Imports, Exports, and Trade Balance in Forest Products: 1990–2002

Source: Howard, J.L. 2003. U.S. Timber Production, Trade, Consumption, and Price Statistics 1965–2002, Table 14. United States Department of Agriculture Forest Service, Forest Products Laboratory, Research Paper FPL-RP-615. Available at: http://www.fpl.fs.fed.us/documnts/fplrp/fplrp615/fplrp615.pdf.

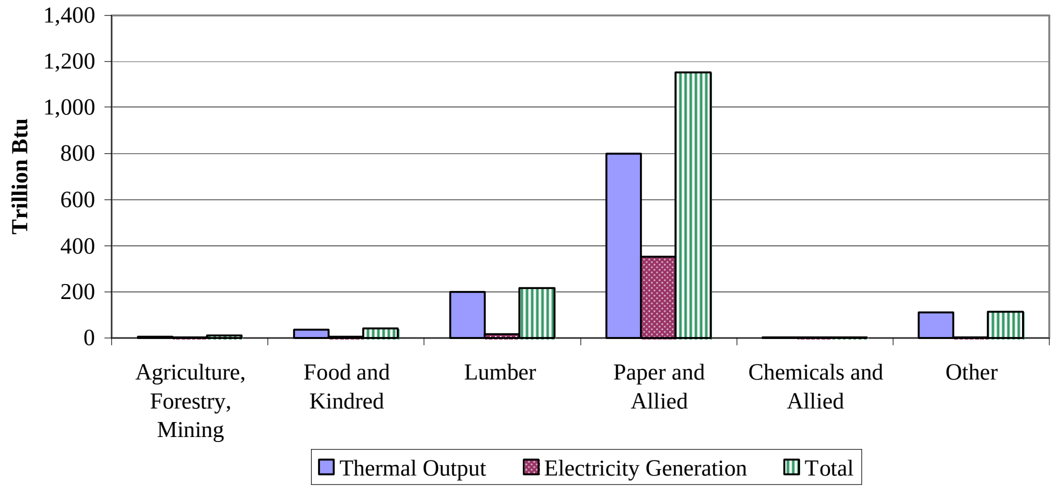

Figure ES-2. Industrial Biomass Energy Use in 2003

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2005b. Renewable Energy Trends 2004. Available at: http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends04.html.

The large majority of biomass consumption in the forest products industry is for process heat and steam in pulp and paper production, but biomass energy is also used to generate electricity to replace purchases from the grid. Pulp and paper production uses significant amounts of electricity and steam (see Figure ES-2) and, as a result, is among the most energy-intensive industries in the economy. Wood residues (e.g., bark) and spent liquor (e.g., black liquor) are the primary sources of biomass fuel at pulp and paper mills. Biomass boilers at pulp and paper mills include chemical recovery furnaces (at mills that practice chemical pulping) and wood-fired boilers. Fossil fuel-fired boilers are also used to generate energy at pulp and paper mills. In the paper manufacturing industry, around 70% of the biomass is used to produce steam, needed mainly for paper drying, although it is also used for other applications, such as pulp digesting. Electricity generation is also an important function of the biomass energy, which is used to run equipment such as pumps and fans, especially in kraft pulp mills.

3. Over the last thirty years, the mix of biomass versus fossil fuels has shifted significantly in the pulp and paper industry from conventional purchased inputs to self-generated fuels (mostly biomass). Specific sources for the energy used in paper manufacturing are shown in Table ES-1. Self-generated sources are now providing close to 60% of the energy needed by the industry, up from only 40% in the early 1970s. This reflects a conscious effort by the industry to improve the energy efficiency of its manufacturing processes and to better utilize available wood residuals to reduce its dependence on fossil fuels. Coal consumption and electricity purchases have increased as newer production equipment has been installed with lower steam but higher electricity requirements. Natural gas and petroleum purchases have fallen in response to higher prices over time. Across all purchased fuels, the total amount of energy bought has fallen by 25%.

4. Several emerging technologies are expected to affect future biomass fuel consumption in the forest products industry, including

- **black liquor gasification (BLG) and biomass gasification combined cycle (BGCC)**, particularly at kraft pulp mills, which could transform the pulping industry in terms of its energy output, economics, and environmental footprint;
- **fluidized bed biomass boilers**, which can more efficiently convert lower-quality biomass fuels such as bark and pulp and paper mill sludge into energy;
- **closed-loop drying and energy systems at wood products facilities** that provide both greater energy efficiency and environmental control; and
- **cogeneration systems at lumber mills** that allow lumber mills to convert biomass to energy for both on-site use, and for sale to the national electricity grid.

5. Environmental regulations and policies have had substantial effects on the energy technologies employed in forest product facilities and the corresponding use of biomass as a fuel. As a major user of energy, fiber inputs, water, and chemicals, the forest products industry is subject to a wide range of regulations to protect air quality and water quality and to ensure proper disposal of solid waste. As a result, capital expenditures have increased to limit air and water pollution, recover waste products, use recycled feedstocks, and reduce energy use. Many of these policies impact biomass consumption at forest products facilities.

Table ES-1. Sources of Energy in the U.S. Pulp and Paper Industry

	1972		2000	
Fuel Type	**Trillion Btu**	**% of Total**	**Trillion Btu**	**% of Total**
Purchased				
Electricity	93.7	4.4%	155.3	7.0%
Steam	22.6	1.1%	33.9	1.5%
Coal	224.7	10.7%	265.8	12.0%
Petroleum	469.4	22.3%	102.2	4.6%
Natural gas	443.9	21.1%	395.6	17.8%
Other[a]	4.3	0.2%	24.1	1.1%
Excess energy sold	–13.1		–44.8	
Total purchased	1,245.5	59.1%	932.0	41.9%
Self-Generated				
Hogged fuel and bark	136.5	6.5%	327.4	14.7%
Spent liquor (solids)	698.4	33.2%	895.0	40.2%
Hydroelectric	9.2	0.4%	5.0	0.2%
Other	3.0	0.1%	19.9	0.9%
Total self-generated	847.1	40.2%	1,247.2	56.1%
Gross Energy Use[b]	2,105.7	100.0%	2,224.1	100.0%

[a]*Includes liquefied petroleum gas (LPG) and other purchased energy.*

[b]*Includes electricity and steam sold to off-site users.*

Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program (EERE). 2005. Energy and Environmental Profile of the U.S. Pulp and Paper Industry. Prepared by Energetics Corporation. Available at: http://www.eere.doe.gov/industry/forest/pdfs/pulppaper_profile.pdf.

Of particular note are the gasification combined cycle technologies described in Box ES-1.

Biomass fuel usage can, in many cases, reduce the stream of potential pollutants released to the environment and lead to more efficient conversion of raw material to finished product. Several recently promulgated environmental regulations, such as the 2005 rules to set National Emission Standards for Hazardous Air Pollutants (NESHAP) and control emissions from forest products and industrial boilers, are significant rules for the industry but will not likely cause substantial impacts on the use of biomass as an energy source in the forest products industry. However, increased regulation of particulate matter (PM) emissions could affect biomass consumption, as PM is released through the combustion of biomass in boilers at forest products facilities. The extent to which biomass boilers will be targeted relative to other sources is unknown at this time.

Box ES-1. Gasification Combined Cycle Technologies

BLG technology uses heat to convert the organic compounds in black liquor to a hydrogen-rich synthetic gas (syngas), leaving the residual pulping chemicals for reuse. The syngas can be used to power the gasification unit, and the rest can be fired in a gas turbine, with the exhaust used to raise steam that can be passed through a steam turbine to generate additional electric power, displacing fossil fuels such as natural gas or coal. This overall process is sometimes referred to as the black liquor gasification combined cycle (BLGCC) process. In addition to generating electric power, the syngas can be converted to supply a variety of fuel and commodity chemical markets. The benefits of BLG relative to conventional technology are expected to include increased efficiency in energy conversion and chemical recovery, reduction/elimination of the smelt-water explosion hazard, reduced maintenance costs, creation of syngas conversion products, and lower emissions of pollutants.

Biomass (wood) gasification systems for generating power at pulp mills are also under development. Biomass gasification would produce gas fuel from the gasification of wood residuals and pulp mill sludges, which can then be used to replace the fossil fuels currently being burned in power boilers.

BLGCC and BGCC technologies are the core technologies for industry's **Integrated Forest Products Biorefinery** (IFPB) concept. When combined under the IFPB, these technologies offer mills the potential to more than double the electricity generation from captive self-generated fuels.

In the American Forest and Paper Association's (AF&PA's) Agenda 2020, gasification was identified as one of its high priority research areas. Through the Agenda 2020 process, gasification demonstration projects were undertaken at three facilities. These three projects have been completed and they are currently awaiting commercialization throughout the industry pending the outcome of current economic feasibility studies.

The preliminary economics of gasification technologies appear promising. The capital costs of a BLG system (including the gasification, biomass boiler, and combined cycle islands) are comparable to the capital costs of conventional technology (e.g., $117 million for BLG system versus $100 million for Tomlinson Recovery Furnace), but the operation and maintenance costs for gasification may be higher. However, the gasification also generates by-products that are estimated to more than pay for the higher operating and maintenance costs. Mills utilizing gasification technology could use the output from the BLGCC system to displace fossil fuel use at the mill and/or export power to the grid.

If they prove to be economically and commercially viable for the entire industry, biomass and BLGCC technologies could make substantial reductions in greenhouse gas emissions compared to conventional technology. When gasification is combined with electricity generation, emission reductions could also be obtained for PM, HAP, SO_2, CO, VOC, NO_X, and TRS (with H_2S scrubbing or recycling).

6. A number of policy proposals under consideration related to greenhouse gas (GHG) emissions reductions may have significant direct and indirect impacts on the forest products industry. These environmental policies could have implications for both the biomass and fossil fuel energy consumption of the industry. Biomass fuels are considered carbon neutral and do not contribute to overall emissions of carbon dioxide ($CO_{2)}$—the primary greenhouse gas. While there are currently only limited mandatory controls on GHG emissions in the United States, for companies undertaking voluntary actions, biomass may be an attractive fuel source. In addition, potential future environmental policies may alter the relative prices of biomass energy versus fossil fuels and might even affect overall availability of biomass. These effects could be the result of direct regulations or spillover effects from policies in other industries such as electricity generation.

Much of the focus on policies to reduce GHG emissions is at the state level, where the policies are often bundled with other initiatives to more broadly increase the amount of renewable fuels in our energy portfolio or otherwise generate "green" energy. A relatively large number of states in the country now have current or proposed renewable portfolio standards (RPS) and green marketing/pricing programs. National-level standards have also been proposed, if not implemented. For example, in 2003 Senator Jeff Bingaman (D-N.M.) of the Senate Committee on Energy and Natural Resources requested that EIA analyze a proposal specifying a RPS with an incremental increase in renewables of 10% by 2020 (EIA, 2003). If these types of policies unfold in a significant way in the future, they could have profound effects on the use of renewable biomass as an energy source in the forest products industry. They could also increase the demand for all forms of biomass and drive up raw material costs for the industry.

7. Many other factors also affect the prospects for biomass energy use in the forest products industry, including equipment replacement schedules, expectations of future relative energy prices, and the complexities associated with integrating changes in energy sources with all other technological and economic decisions in the forest products facility. Decisions on biomass energy technologies cannot be viewed independently of all other operating decisions made at a forest products facility. For instance, capital replacement decisions in the industry depend in large part on the vintage of the current capital stock. Approximately 50% of existing chemical recovery furnaces and wood-fired boilers were originally installed more than 30 years ago. Although there have been incremental upgrades, repairs, and other modifications made to these furnaces and boilers since they were originally installed, many of these units will need to be replaced over the next 5 to 20 years, which provides a window of opportunity for these mills to consider converting to black liquor and/or wood gasification systems for all or part of their process, if these options prove to be economic.

Technology adoption, and hence biomass energy consumption, will depend on technology costs and efficiencies, as well as on prices of fossil fuels (and purchased biomass, if used). The availability, or perceived availability, of biomass may also alter facilities' decisions. In the short run, since fossil fuels are used to supplement self-generated biomass and/or generate electricity, companies evaluate costs of alternative energy sources when choosing a fuel mix. Over longer time periods, technologies can be changed or improved to increase biomass energy utilization. Other factors that also affect the use of biomass as a fuel include the cost and availability of industrial landfills and the ability of forest products facilities to find beneficial uses for wood waste and pulp mill WWT sludge.

8. Future Biomass Use Trends. It is difficult to predict exactly how the mix of technological, economic, and policy factors will combine to affect future biomass consumption in the forest products industry. Consequently, qualitative directional indicators are assigned to these various points, as shown in Table ES-2 (details behind these points are discussed throughout the text).

Table ES-2. Expected Changes in Biomass Energy Consumption and Contributing Factors

Type of Biomass	**Quantity Consumed In 2000** (trillion Btu, unless noted)[a]	**Expected Directional Changes through 2010**		**Primary Factors Contributing to Increased Consumption**	**Primary Factors Contributing to Decreased Consumption**
		Quantity of Biomass Fuel Generated	**Quantity of Biomass Fuel Consumed**		
Spent (black) liquor	895	Flat	Flat	Successful full-scale implementation of BLG at kraft pulp mill	Foreign competition leading to mill closures and production curtailments
Wood residuals	327	Increase	Increase	(1) Increases in fossil fuel prices (2) Disruptions in availability of fossil fuels (3) Financial incentives for using renewable energy fuels (4) Successful full-scale implementation of wood gasification at pulp mill	(1) Lower fossil fuel prices, especially natural gas (2) Competition for biomass fuel (e.g., from utilities)
Pulp and paper WWT sludge	3.7 million BTU	Increase	Increase	(1) Increases in fossil fuel prices (2) Disruptions in availability of fossil fuels (3) Increased used of recycled fiber in papermaking (4) Decreases in landfill space; increases in landfill costs	(1) Lower fossil fuel prices, especially natural gas (2) Internal and external competition for sludge (e.g., recycling of fiber to process; sale of sludge to end users, such as asphalt roofing manufacturers)

[a] *Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program (EERE). 2005. Energy and Environmental Profile of the U.S. Pulp and Paper Industry.*

.[b] *Source for tons of sludge: National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI). 1999. "Solid Waste Management Practices in the U.S. Paper Industry—1995." Technical Bulletin No. 793. Research Triangle Park, NC: NCASI. September 1999.*

[c]*Source for sludge BTU value: Charlson, Steve. 1999. Bubbling Fluidized Bed Installation Capitalizes on Sludge. Presented at 1999 TAPPI Engineering Conference. Anaheim, CA. September 12-16, 1999.*

1. Introduction

The EIA is seeking improved information on biomass energy consumed for heat and steam in the forest products industry. In this industry, technologies are expected to be changing over time, along with primary fuel prices and environmental regulations; thus, the quantities and types of energy used will be changing. This report supports EIA's goals, both broad and specific by providing a current, impartial assessment of issues of general interest to the nation's energy concerns and addresses specific technological, economic, and environmental issues related to biomass use in the forest products sector. The report's objectives are to produce:

- context information for the forest products industry, its current economic and technological conditions;
- current state and future trends of technologies, markets, and regulatory factors affecting biomass consumption for energy purposes in the forest products industry; and
- discussions of the amount of biomass consumed now and in the near future.

Following this introduction, the report is organized as follows.

- **Section 2** defines the forest products industry, provides an overview of its economic and technological characteristics, and summarizes the current use of biomass as a fuel source at forest products facilities.
- **Section 3** presents in more specific detail the existing technologies at forest product facilities that use biomass and convert it to energy for the production process. The chapter highlights recent trends in energy recovery within the industry.
- **Section 4** describes emerging technologies that could substantially alter the use of biomass at forest product facilities. These technologies include the potential for gasification of wood material and black liquor and enhancements in boiler technologies to improve energy recovery.
- **Section 5** describes the important role that environmental factors play in determining the production and energy technologies adopted at forest products facilities. These factors include responses to regulations that control air, water, and solid waste pollution, as well as initiatives to enhance the use of renewable energy sources to address GHG concerns.
- **Section 6** addresses various market and logistical considerations associated with adopting new technologies at forest products facilities, including the optimal replacement of existing capital stock and the availability and price of biomass fuels versus conventional fossil fuels over the planning horizon.
- **Section 7** concludes the report and examines possible trends in biomass energy use based on expected industry and market changes.

2. The Forest Products Industry

This section provides an overview of the U.S. forest products industry, its economic characteristics, products produced, technologies employed, and energy consumed. This report focuses largely on technologies used in the primary manufacturing components of the forest products industry and their related biomass energy consumption. The industry is defined as including the wood product manufacturing industry (NAICS 321) and the paper manufacturing industry (NAICS 322). These sectors convert raw wood supply into commercial products and are therefore most relevant to the issues of biomass consumption for energy. However, to provide context for this industrial activity, upstream sectors such as forestry and logging (NAICS 113), and downstream sectors such furniture (NAICS 337), construction (NAICS 23), and printing (NAICS 323) are also addressed in places. See EERE (2005a) for additional discussion of the pulp and paper industry.

2.1 Overview of the Industry

Figure 2-1 illustrates the flow of raw material from the harvesting of timber in the forest to the manufacture and use of final products. The first stage, forestry and logging, involves the cultivation and extraction of timber. Timber removed from the forest is commonly referred to as roundwood, which is used either for fuelwood or as an input to forest products production. Sawlogs, which are used in the production of lumber, plywood, and other structural products, are typically roundwood that is larger in diameter, straighter, and free of major defects. Pulpwood, which is used in the production of pulp, paper, and paperboard, is typically smaller in diameter or otherwise less suited for use in structural wood products. Chips and other residue from the logging and milling operations can also be used as inputs to both the paper industry and the wood products industry (e.g., as an input to particleboard [PB]). Lumber, panels, paper, and paperboard comprise literally thousands of primary products that are used as inputs to other industries, such as furniture, construction, and printing, which produce the ultimate finished goods and services used by consumers.

The United States is the world's leading producer and consumer of forest products, accounting for about one-quarter of the world's production and almost 30% of the world's consumption. In 2002, the United States produced 16.5 billion cubic feet (ft^3) of timber, had net imports of 3.1 billion ft^3, and consumed 19.6 billion ft^3 (Table 2-1). On a per-capita basis, this represents an average of 718 pounds of paper products and 18 ft^3 of lumber and structural panel products. By the middle of this century, the U.S. Department of Agriculture (USDA) Forest Service projects that U.S. demand for forest products will reach 26.5 billion ft^3 annually (AF&PA, 2002a).

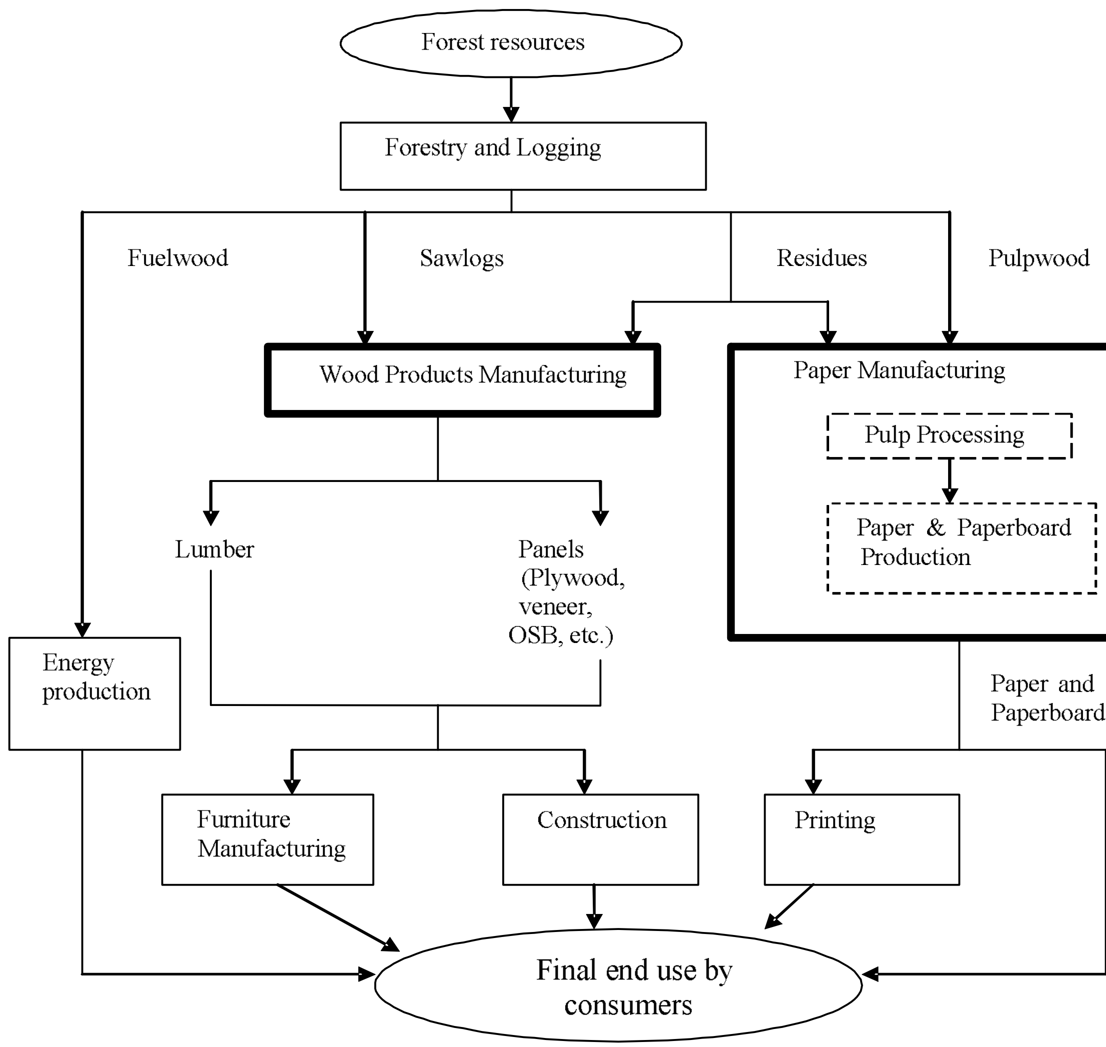

Figure 2-1. Material Flow from the Forest to Final Products

Table 2-1 quantifies the flow of raw material harvested from forests (roundwood) to its use in primary product production. Roundwood is classified into two categories: industrial use (for lumber, plywood, paper, etc.) and fuelwood, with the former the dominant use by far in the United States, with over 90% of the total. The data can also be separated into four subcategories—production, consumption, imports, and exports—to further define sources and destination of the raw material flow. This report focuses on forest products production facilities in the United States; thus the production columns in Table 2-1 are of primary interest.

Table 2-1. Production, Consumption, and Trade of Timber by Major Product Categories (in billion ft^3 roundwood equivalent)

	Industrial Roundwood Use																						
	All Products (including fuelwood)		Total Use (excluding fuelwood)				Lumber				Plywood and Veneer				Pulpwood-Based Paper Products				Other Industrial Products, Production and Consumption	Logs		Pulpwood Chips		Fuelwood Production and Consumption
Year	Production	Consumption	Production	Imports	Exports	Consumption	Production	Imports	Exports	Consumption	Production	Imports	Exports	Consumption	Production	Imports	Exports	Consumption		Imports	Exports	Imports	Exports	
1995	17.6	19.2	15.5	3.9	2.3	17.1	6.9	2.5	0.46	8.9	1.3	0.11	0.089	1.3	6.1	1.2	0.91	6.4	0.39	0.013	0.45	0.019	0.38	2.2
1996	17.3	18.9	15.3	3.9	2.3	17.0	7.0	2.7	0.45	9.2	1.3	0.10	0.087	1.3	5.9	1.1	0.89	6.2	0.34	0.018	0.42	0.012	0.42	1.9
1997	17.4	19.1	15.7	4.1	2.3	17.4	7.2	2.7	0.46	9.4	1.2	0.11	0.103	1.2	6.1	1.3	0.93	6.4	0.33	0.020	0.38	0.004	0.42	1.7
1998	17.3	19.7	15.7	4.3	2.0	18.0	7.2	2.8	0.35	9.7	1.2	0.13	0.055	1.3	6.2	1.4	0.84	6.7	0.31	0.030	0.32	0.007	0.41	1.6
1999	17.3	19.8	15.7	4.4	1.9	18.2	7.5	2.9	0.41	10.0	1.2	0.15	0.055	1.3	5.9	1.4	0.75	6.5	0.30	0.047	0.33	0.002	0.41	1.6
2000	17.3	19.8	15.6	4.6	2.1	18.2	7.4	2.9	0.44	9.9	1.2	0.15	0.051	1.3	6.0	1.5	0.79	6.7	0.30	0.072	0.42	0.002	0.35	1.6
2001	16.5	19.4	14.9	4.7	1.8	17.8	7.1	3.0	0.36	9.7	1.1	0.18	0.039	1.2	5.8	1.5	0.76	6.5	0.32	0.073	0.40	0.001	0.26	1.6
2002	16.5	19.6	15.0	4.9	1.8	18.1	7.3	3.2	0.36	10.1	1.1	0.21	0.034	1.2	5.7	1.4	0.78	6.4	0.32	0.086	0.39	0.002	0.19	1.5

Source: Howard, J.L. 2003. U.S. Timber Production, Trade, Consumption, and Price Statistics 1965–2002, Table 5a. United States Department of Agriculture Forest Service, Forest Products Laboratory, Research Paper FPL-RP-615. Available at: http://www.fpl.fs.fed.us/documnts/fplrp/fplrp615/fplrp615.pdf.

Lumber production is the leading use of industrial roundwood in the United States, accounting for about 7.3 billion ft^3 of total roundwood use in 2002. This is followed by the consumption of pulpwood to produce paper products (5.7 billion ft^3) and roundwood to produce plywood and veneer (1.1 billion ft^3). Fuelwood accounts for about 1.5 billion ft^3, or just under 10% of all roundwood. Figure 2-2 shows that the share of roundwood used for lumber rose between 1995 and 2002, the share for fuelwood declined slightly, and the other uses stayed roughly the same.

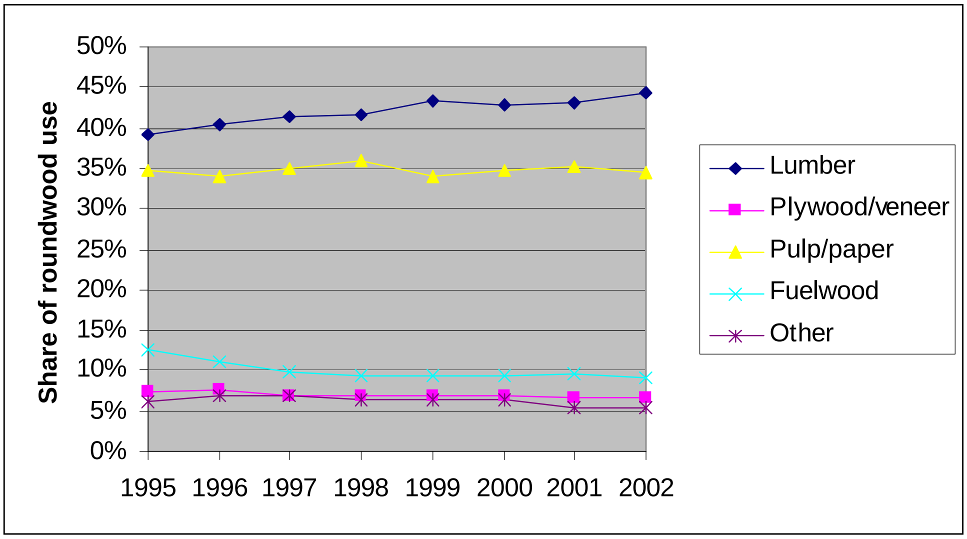

Figure 2-2. Shares of Roundwood Used in Forest Product Production in the United States: 1995–2002

Source: Howard, J.L. 2003. U.S. Timber Production, Trade, Consumption, and Price Statistics 1965–2002, Table 2-1. United States Department of Agriculture Forest Service, Forest Products Laboratory, Research Paper FPL-RP-615. Available at: http://www.fpl.fs.fed.us/documnts/fplrp/fplrp615/fplrp615.pdf.

As a group, production by the forest products industry contributes significantly to the U.S. economy in terms of employment and output (Table 2-2). Almost 1.1 million people are employed in the primary manufacturing activities of wood products (BEA, 2005). Related employment effects are almost 10 times larger if upstream wood product supplies (forestry and logging) and downstream users of forest products (furniture, construction, and printing) are considered. AF&PA (2002) also estimates that for every job in a forestry-related industry, another two jobs are created indirectly in other industries engaged in the transportation, distribution, and sales of forest products.

The value of economic output from this industry is also substantial, with the primary manufacturing sectors accounting for about $265 billion in annual revenue. This amount grows to about $400 billion when forestry and furniture are included, and to over $1.5 trillion when construction and printing are counted, amounting to about 8% of total U.S. economic output.

Table 2-2. Forest Product–Related Employment and Output, 2004

	Employment (10^3)	Output (billion $)
Forestry and Logging[a]	684	61.0
Primary Forest Products Manufacturing		
Wood products	568	107.2
Paper	495	157.7
Downstream Sectors Using Forest Products		
Furniture and related products	572	80.8
Construction	7,215	1,050.5
Printing and support activities	662	91.2
Total of all Forest-Related Sectors	**10,196**	**1,548**

[a] *Forestry employment data includes some fisheries employment, which cannot be separated out.*

Source: U.S. Bureau of Economic Analysis (BEA). 2005. Series: Gross Output by Industry in Current Dollars, Quantity Indexes by Industry, Price Indexes by Industry 1998–2003. The Industry Economics Division, The Bureau of Economic Analysis, U.S. Department of Commerce, Washington, DC. Available at: http://www.bea.gov/bea/dn2/gdpbyind_data.htm on 12/19/2005.

Although a sizeable portion of U.S. forest products are exported (over $18 billion), the country consumes more than it produces, which resulted in a trade deficit of $13.6 billion in 2002 (Table 2-3). The trade balance varies by product, with a proportionately large deficit in lumber and other wood products, a smaller deficit in paper products, and a trade surplus in raw wood products (i.e., sawlogs, pulpwood, and chips).

The U.S. forest products trade deficit has widened substantially in recent years (Figure 2-3). In the early 1990s, imports and exports were roughly offsetting at around $17 to $18 billion each. Since the mid-1990s, however, growth in the value of imports has substantially outpaced export values, and the early 21st century has been a period of historically high deficits for the United States. Figure 2-3 only goes through 2002, but data from the U.S. International Trade Commission (ITC) show that the forest products trade gap widened by another $7.7 billion between 2002 and 2004, as imports surged and exports remained flat (ITC, 2005)

By far, our largest trading partner is Canada, which supplies about 60% of all U.S. forest product imports and purchases about one-third of all U.S. forest product exports (ITC, 2005). However, this pattern has changed somewhat in recent years. For example, between 2000 and 2004, Canada’s share of U.S. imports declined from 65% to 58%, while China’s share rose from 5% to over 9%, and Brazil’s share rose from 3% to almost 5%.

Table 2-3. Value of Forest Products Imports, Exports, and Trade Balance, 2002 (million $)

Product	Imports	Exports	Trade Balance
Raw Wood			
Logs	$202.5	$1,207.8	$1,005.3
Pulpwood (roundwood and chips)	$10.1	$299.8	$289.7
Total	$212.6	$1,507.6	$1,295.0
Wood Products			
Lumber	$6,887.3	$1,824.6	–$5,062.8
Veneer	$454.7	$457.6	$2.9
Plywood	$1,046.3	$150.8	–$895.5
Particleboard (PB)	$269.6	$41.0	–$228.6
Medium density fiberboard (MDF)	$205.5	$46.8	–$158.6
Oriented strandboard (OSB)/waferboard	$1,076.8	$41.0	–$1,035.8
Hardboard	$406.9	$69.3	–$337.6
Total	$10,347.1	$2,631.1	–$7,716.0
Paper Products			
Wood pulp	$2,294.2	$2,612.2	$318.0
Paper and board	$14,084.2	$9,805.6	–$4,278.5
Recovered paper	$54.7	$1,077.2	$1,022.4
Total	$16,433.1	$13,495.0	–$2,938.1
Other Wood Products[a]	$5,354.8	$1,104.9	–$4,250.0
Total of All Forest Products	**$32,347.6**	**$18,738.6**	**–$13,609.0**

[a] *Includes poles and piling, fuelwood, wood charcoal, cork, wood containers, wood doors, and other miscellaneous products*

Source: Howard, J.L. 2003. U.S. Timber Production, Trade, Consumption, and Price Statistics 1965–2002, Table 13. United States Department of Agriculture Forest Service, Forest Products Laboratory, Research Paper FPL-RP-615. Available at: http://www.fpl.fs.fed.us/documnts/fplrp/fplrp615/fplrp615.pdf.

The following discussion provides further information on the two components of the industry that are the largest consumers of wood in the United States: paper and wood products. These are presented below, in order of their importance to overall biomass energy consumption.

2.1.1 Paper Industry

The paper industry, also referred to as "pulp and paper" or "pulp, paper, and paperboard," has an illustrious cultural, technological, and economic history. The Chinese are generally credited with inventing paper about 2,000 years ago. Subsequently, the art of papermaking spread across Asia, Europe, and into the American colonies in the 17th century (Gregory, 1987). Today, pulp, paper, and paperboard products are produced in over 600 production facilities across the nation (EERE,

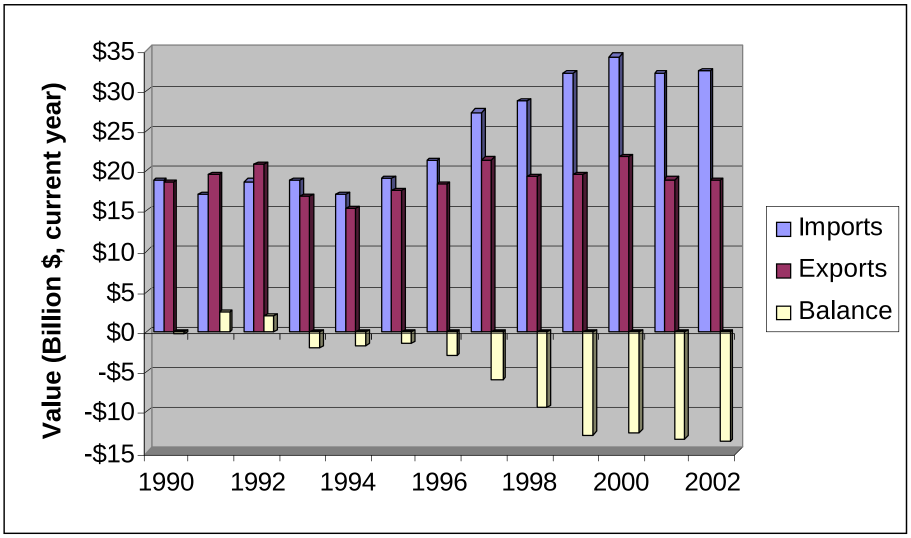

Figure 2-3. Imports, Exports, and Trade Balance in Forest Products: 1990–2002

Source: Howard, J.L. 2003. U.S. Timber Production, Trade, Consumption, and Price Statistics 1965–2002, Table 14. United States Department of Agriculture Forest Service, Forest Products Laboratory, Research Paper FPL-RP-615. Available at: http://www.fpl.fs.fed.us/documnts/fplrp/fplrp615/fplrp615.pdf.

2005a), with the United States accounting for roughly 30% of the world's paper and paperboard production (EPA, 2002).

Although the United States is a net exporter of pulpwood, it is also a net importer of paper, board, and pulp (see Table 2-3). Major export markets for U.S. pulp and paper products are Japan, Italy, Germany, Mexico, and France. As discussed above, overall forest product exports have been declining and imports have been increasing in recent years, and the pulp and paper industry has followed those broad trends. For instance, between 1997 and 2000, exports declined 5.5%, and imports increased by more than 20%. These changes were partly due to a strong dollar in this period and to the recent slowdown of the U.S. economy (AF&PA, 2002a). In addition, other nations are becoming more competitive. Countries such as Brazil, Chile, and Indonesia now have modern pulp facilities, along with faster-growing trees and lower labor costs than the United States (EPA, 2002). Latin American and European countries also are adding papermaking capacity.

Another trend in the pulp and paper industry is the increasing use of recovered paper, which has lowered consumption of pulpwood in U.S. mills. Nearly 50% of paper is now recovered and used either as recycled paper or in products such as home insulation (AF&PA, 2005). Use of recycled paper as a feedstock can affect biomass energy consumption in paper production, because most biomass fuel within a pulp and paper facility comes from the production of virgin fiber, which involves converting whole logs into pulp (EERE, 2005a). Recycled paper does not generate this residual biomass waste.

2.1.2 Wood Products Industry

The wood products industry encompasses lumber, plywood, veneer, and other reconstituted wood products and is commonly referred to as “lumber and wood products” because of the dominant role that lumber plays in its economic composition. The various components of the industry are discussed below.

Lumber. The lumber industry includes establishments, referred to as “sawmills,” that transform harvested logs into products such as framing lumber (e.g., two-by-fours, structural beams, flooring, and a range of dimensional wood products used primarily in the construction and furniture industries).[1]

The lumber industry produced close to $53 billion of output in 2003 and employed almost 200,000 people (BLS, 2005; BEA, 2005). The South is the largest producer in the United States, followed by the West (i.e., Pacific Northwest and Northern Rockies) and North (i.e., Lake States and Northeast), respectively (EPA, 1995). Softwood lumber, the dominant commercial species, is produced in the South and West, while the North produces mostly hardwoods. Softwood boards are used primarily for structural framing of light construction. Hardwoods are used for flooring, furniture, and crating. Softwood plywood and veneer are primarily used for construction (90% by volume). Hardwood plywood and veneer are used typically in furniture. Preserved wood is used primarily in the construction, railroad, and utilities industries.

Lumber accounts for almost 40% of all timber production in United States (see Table 2-1). More than 75% of lumber production and consumption is softwood (Howard, 2003). The lumber industry produced an estimated 48 billion board feet (bbf) of lumber (i.e., softwoods plus hardwoods) in 2002. Lumber production has increased substantially from 1965 levels, but has declined slightly after a peak in 1988 of 50 bbf. Some of this decline can be attributed to legislation to curtail timber harvesting on federally owned lands in the western United States (Wear and Murray, 2004).

In 2002, lumber imports to the United States from all other countries totaled 21.7 bbf, while exports were only 2.2 bbf (Howard, 2003). This difference—net imports—represented about one-fourth of all domestic lumber consumption in 2002. In 2002, 90% of all lumber imports were from Canada, covering nearly 63% of total Canadian lumber production. In the past, U.S. lumber exports were higher, growing steadily from 1965 through 1990, and reaching a record high of nearly 4.6 bbf in 1988, which later fell to 2.1 bbf by 2002.

Lumber consumption in the United States for all uses was 67.7 bbf in 2002, or roughly 235 board feet (bf) per capita, which is below the high of 245 bf set in 1999 (Howard, 2003). Overall, 40%

[1] The lumber industry includes sawmills, wood preservation, cut stock, resawing lumber, and planing.

of this consumption was for housing, 8% for new nonresidential construction, 13% for manufacturing, and 11% for shipping materials (e.g., pallets, containers, and dunnage). This demonstrates that the strength of construction markets is a very important determinant in the fate of the lumber and wood products industry. In recent years, the contribution of the construction market to U.S. GDP has grown continuously from $374 billion in 1998 (4.3% of gross domestic product [GDP]) to $550 billion in 2004 (4.7% of GDP).

Plywood and Veneer. The plywood and veneer industry produced more than $8.5 billion of output in 2003 and employed over 44,000 people (BLS, 2005; BEA, 2005). Softwood plywood production in 2002 was approximately 15.2 billion ft^2 (3/8-in. basis) (Howard, 2003). This production had increased slightly from 1999 levels, but overall declined by 22% between 1994 and 2002. Any future decreases may depend largely on the strength of housing markets and market penetration of OSB, a substitute for softwood plywood. Hardwood plywood production in 2002 was 2 billion ft^2, continuing a downward trend from 1999. The main factor in this decline has been weak demand from the furniture, cabinetry, and fixtures markets.

Imports of softwood plywood, estimated at about 907 million ft^2 in 2002, are very small compared to overall U.S. plywood consumption (Howard, 2003). Hardwood plywood imports were 2.9 billion ft^2, representing 60% of the hardwood plywood consumed in the United States. This continues the trend of import growth for hardwood plywood since 1988. During the 1960s and 1970s, Korea was the principal source of these imports. Now, Canada, Brazil, Malaysia, and the Russian Federation are also major sources, although Asia was still the largest source (52.5%) of U.S. imports in 2002.

Hardwood and softwood exports in 2002 were relatively modest at 180 million ft^2 and 439 million ft^2, respectively. Export levels in this century are lower than peak levels in the 1990s. Export demand comes mainly from Brazil, Indonesia, Malaysia, and the Russian Federation, which represent over 70% of U.S. exports. In the case of veneer, both imports and exports increased between the1990s and 2002. Softwood and hardwood veneer imports were each around 2.3 billion ft^2 in 2002. Softwood veneer exports were 260.3 million ft^2 in 2002, whereas hardwood veneer exports were almost 3.5 billion ft^2.

Reconstituted Wood Products. PB, hardboard, medium density fiberboard (MDF), insulation board, OSB, and engineered lumber are examples of reconstituted wood products. Output of this industry was almost $6 billion in 2003 (BEA, 2005). Approximately 22,000 people worked in this industry in 2002 (USCB, 2002). Production of PB in 2002 totaled 4.4 billion ft^2 (3/4-in. basis), which continues a general increase barring a dip during 2000 (Howard, 2003). Part of the rise in PB production during the 1990s was the result of the strength in housing markets. Exports increased to an estimated 119 million ft^2 in 2002, the third consecutive year of increases, while imports fell by 42% in 2001 to 2002. Apparent consumption of PB rose 6.1% during 2002, after decreasing during 2001. Production of MDF in 2002 was 1.6 billion ft^2 (3/4-in. basis). The major market for MDF is furniture and cabinetry applications because of MDF's attractive finished look.

Hardboard production in 2002 was an estimated 2.9 billion ft^2 (1/8-in. basis). This production level continued a falling trend started in 1983, when hardboard production was 7.3 billion ft^2. Imports of hardboard in 2002 amounted to 2.7 billion ft^2, continuing an upward trend since 1993. Imports accounted for 48% of total U.S. hardboard consumption in 2001. Exports of hardboard declined further in 2002 after a short-lived growth period during the mid-1990s. Exports of hardboard, although declining, still account for 22.3% of total production. Consumption of hardboard in 2002 was 4.9 billion ft^2, which was slightly higher than normal because of a strong housing sector. In 2002, more than half of all hardboard consumed was for residential exterior siding.

Production of insulation board in 2002 was about 2.3 billion ft^2 (1/2-in. basis) or 857,000 tons. Imports and exports of insulation board were relatively small, amounting to 112,000 and 62,000 tons, respectively. Production and trade of insulation board has been flat since 1993 and appears likely to remain so.

2.2 Production Processes

The following sections briefly describe the processes by which paper, lumber, and panel products are made. See EERE (2005) for further discussion of processes in the paper industry and Sections 3 and 4 of this report for additional information on how these production techniques are related to generation and utilization of biomass energy in the forest products industry.

2.2.1 Paper

Typically, paper or paperboard is produced in two sequential processes, which may or may not be co-located at the same facility. First, pulp mills prepare pulp from wood, recycled paper or paperboard, or other cellulose-based materials (e.g., rags). The processes used to prepare pulp are based on the desired end-product and include chemical (e.g., kraft), semichemical, and mechanical techniques. Paper and paperboard mills then take the pulp produced in pulp mills and manufacture a variety of products, such as kraft linerboard (using pulp from chemical pulp mills), paper (using pulp from both chemical and recycled paper mills), corrugating medium (using semichemical pulp), and newsprint (using pulp from mechanical pulp mills).

Table 2-4 provides an overview of process sequences used in pulp manufacturing, and Table 2-5 describes different pulping processes and the main products produced. Around 50% of all pulp is produced using bleached kraft processes, over 30% using unbleached Kraft processes, about 10% is mechanical pulp, and 6% is semichemical pulp.

Table 2-4. Production Process Sequence in Pulp Manufacturing

Process Sequence	Description
Fiber furnish preparation and handling	Debarking, slashing, chipping of wood logs, and then screening of wood chips/secondary fibers (some pulp mills purchase chips and skip this step)
Pulping	Chemical, semichemical, or mechanical breakdown of pulping material into fibers
Pulp processing	Removal of pulp impurities, cleaning and thickening of pulp fiber mixture
Bleaching	Addition of chemicals in a staged process of reaction and washing increases whiteness and brightness of pulp, if necessary
Pulp drying and baling (nonintegrated mills)	At nonintegrated pulp mills, pulp is dried and bundled into bales for transport to a paper mill
Stock preparation	Mixing, refining, and addition of wet additives to add strength, gloss, texture to paper product, if necessary

Source: U.S. Environmental Protection Agency (EPA). 2002. Profile of the Pulp and Paper Industry, Table 6. 2nd Edition. EPA Office of Compliance Sector Notebook Project, Office of Enforcement and Compliance Assurance, EPA, Washington, DC. November 2002.

Table 2-5. Different Pulp Processes

Pulp Process	Description/Principal Products
Dissolving kraft	Highly bleached and purified kraft process wood pulp suitable for conversion into products such as rayon, viscose, acetate, and cellophane
Bleached papergrade kraft and soda Unbleached kraft	Bleached or unbleached kraft process wood pulp usually converted into paperboard, coarse papers, tissue papers, and fine papers for business writing and printing
Dissolving sulfite	Highly bleached and purified sulfite process wood pulp suitable for conversion into products such as rayon, viscose, acetate, and cellophane
Papergrade sulfite	Sulfite process wood pulp with or without bleaching, used for products such as tissue papers, fine papers, and newsprint
Semichemical	Pulp is produced by chemical, pressure, and occasionally mechanical forces with or without bleaching used for corrugating medium (cardboard), paper, and paperboard
Mechanical pulp	Pulp manufactured by stone groundwood, mechanical refiner, thermo-mechanical, chemi-mechanical, or chemi-thermo-mechanical means for newsprint, coarse papers, tissue, molded fiber products, and fine papers
Secondary fiber deink	Pulps from recovered paper or paperboard using a chemical or solvent process to remove contaminants such as inks, coatings, and pigments used to produce fine, tissue, and newsprint papers
Secondary fiber nondeink	Pulp production from recovered paper or paperboard without deinking processes to produce tissue, paperboard, molded products, and construction papers
Nonwood chemical pulp	Production of pulp from textiles (e.g., rags), cotton linters, flax, hemp, tobacco, and abaca to make cigarette wrap papers and other specialty paper products

Source: U.S. Environmental Protection Agency (EPA). 2002. Profile of the Pulp and Paper Industry, Table 2. 2nd Edition. EPA Office of Compliance Sector Notebook Project, Office of Enforcement and Compliance Assurance, EPA, Washington, DC. November 2002.

The paper/paperboard manufacturing process consists of wet-end operations that form a sheet of paper from wet pulp, followed by dry-end operations that include drying the paper product, application of any surface treatments, and spooling for storage. Typically, wet pulp is spread on a belt and repeatedly rolled so that fibers synthesize and produce a paper. Various finishing operations give paper the desired color, thickness, and texture. Paper and paperboard manufacturers use nearly identical processes; the main difference between the two products is their thickness (i.e., paperboard is thicker by more than 0.3 mm).

Figure 2-4 provides a schematic description of a representative integrated kraft pulping mill and papermaking operation.

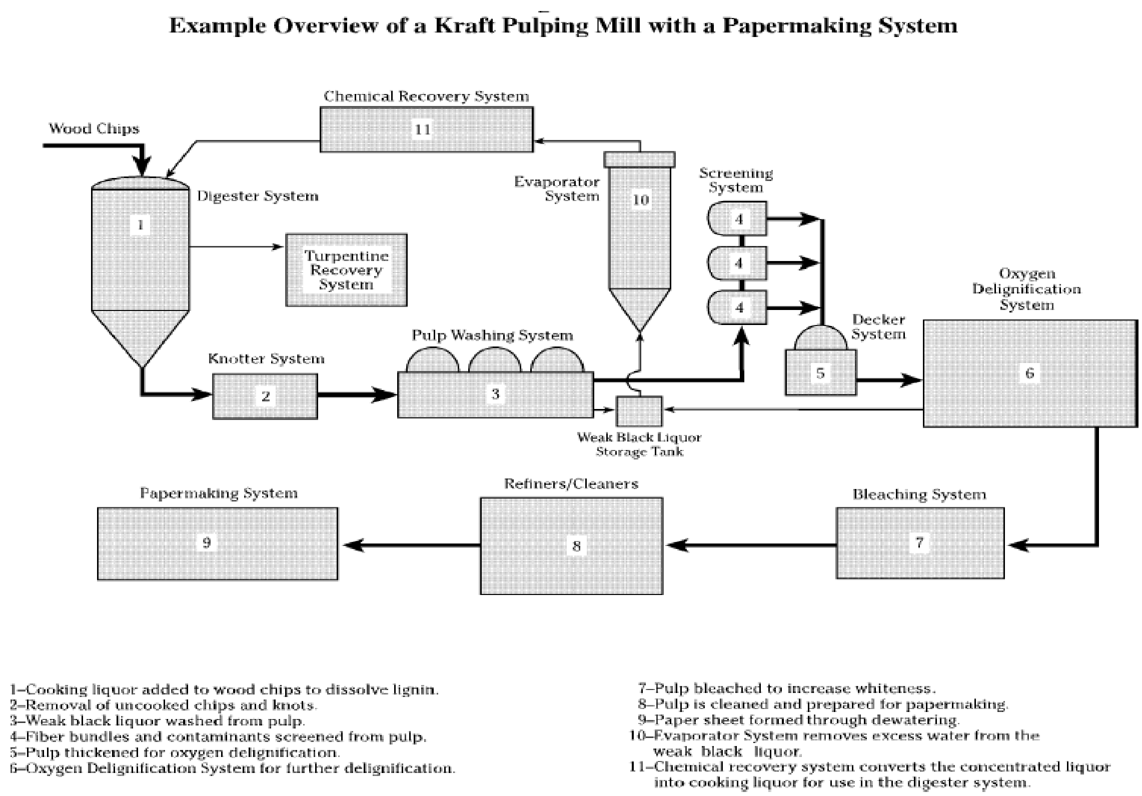

Figure 2-4. Integrated Kraft Pulp and Paper Mill

Source: U.S. Environmental Protection Agency (EPA). 1998. Pulp and Paper NESHAP: A Plain English Description. Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA-456/R-98-008. November 1998.

2.2.2 Lumber

The lumber production process is illustrated in Figure 2-5. After whole logs are transported to a sawmill, they are debarked and cut into shorter lengths, which are then finished to meet subsequent product requirements (EPA, 1995). Bark, shavings, sawdust, and chips generated during this process are often used as hog fuel for boilers or sold for use in PB manufacturing or

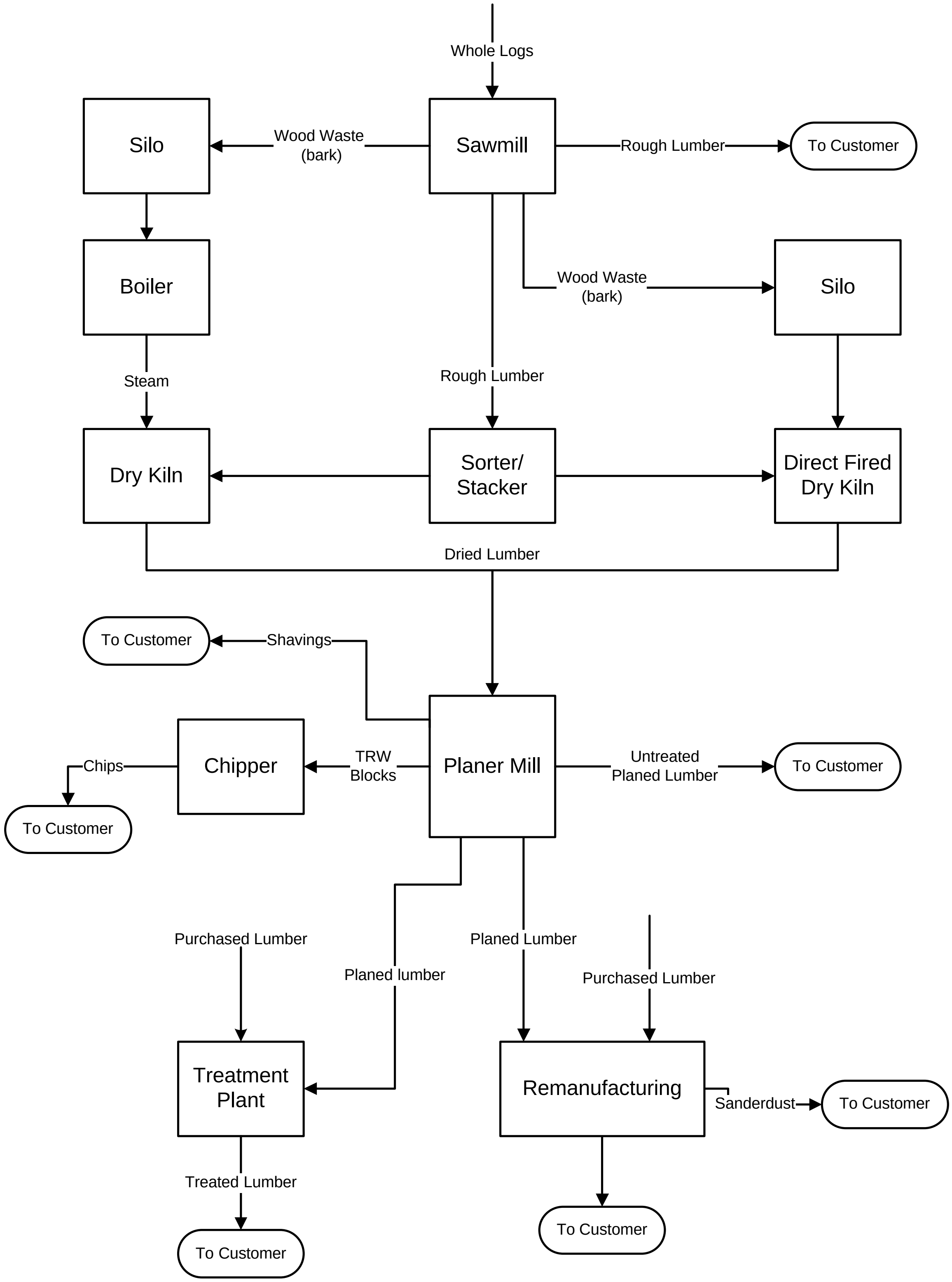

Figure 2-5. Example Flow Diagram for a Lumber Production Facility

Source: U.S. Environmental Protection Agency (EPA). 1995. Profile of the Lumber and Wood Products Industry, Exhibit 5 (modified). EPA Office of Compliance Sector Notebook Project, Office of Enforcement and Compliance Assurance, EPA, Washington, DC. September 1995.

as mulch. Most lumber is dried either through air or kiln drying. Chemicals are frequently applied at the sawmill to prevent sap-staining or to preserve wood used in electricity transmission poles and other construction.

2.2.3 Veneer and Plywood

Figure 2-6 depicts the production process for a veneer, which is a thin sheet of wood peeled from a log, and for plywood operation. The general processes for making either softwood or hardwood plywood are the same: logs are debarked and steamed or soaked, veneer sheets are cut, the veneer is then dried and prepared, glue is applied, the sheets are pressed, and resulting panels are trimmed and sanded (EPA, 1995). Almost all hardwood and most softwood lumber is heated using steam or hot water to soften the wood. The majority of veneer is produced by peeling (i.e., rotary cutting), although slicing is used to produce decorative hardwood veneers. After the veneer is peeled and clipped, it is dried using forced hot air or steam. Then, different adhesive application systems are used to layer veneer sheets together into plywood. Softwood plywood is made by layering softwood veneers together with glue. Hardwood veneer is made by gluing hardwood sheets on the front and back of softwood veneers, lumber, or other panels (e.g., PB). The layered panels are then compacted in a cold press, followed by hot press. After pressing, panels are trimmed and sanded to finish them.

2.2.4 Reconstituted Wood Products

Reconstituted wood products, such as PB, MDF, hardboard, and OSB, are pressed mats composed of furnish (raw wood), combined with resins and other additives. In general, the manufacturing process involves reducing the size of the wood, followed by drying (except for wet process boards), adhesive application, forming, hot pressing, and finishing (EPA, 1995). Figure 2-7 illustrates this process flow for reconstituted wood products.

The furnish used to manufacture PB—either green or dry wood residues—are ground into particles of varying sizes using flakers, mechanical refiners, and hammer mills. The furnish is then dried using rotating drum dryers and blended with synthetic adhesives, wax, and other additives. This mixture is formed into mats, which are hot pressed to increase their density and to cure the resin. The process to manufacture MDF is mostly similar to that of PB, except the wood furnish is rubbed apart into fibers instead of being mechanically broken apart, and the blending process usually occurs as the furnish is dried (i.e., resin and wood fiber are mixed as they are pneumatically blown through a tube dryer). Hardboard is a high-density version of MDF/PB and comes in three types classified by their manufacturing processes (either wet, wet/dry, or dry). The furnish used to manufacture OSB is specially flaked from roundwood. OSB is then formed in a dry process by mechanically orienting the wood strands. Engineered lumber is also produced from strands of veneer and adhesives and has the advantage of being produced from small, low-grade logs with more uniform quality and straightness than sawn lumber.

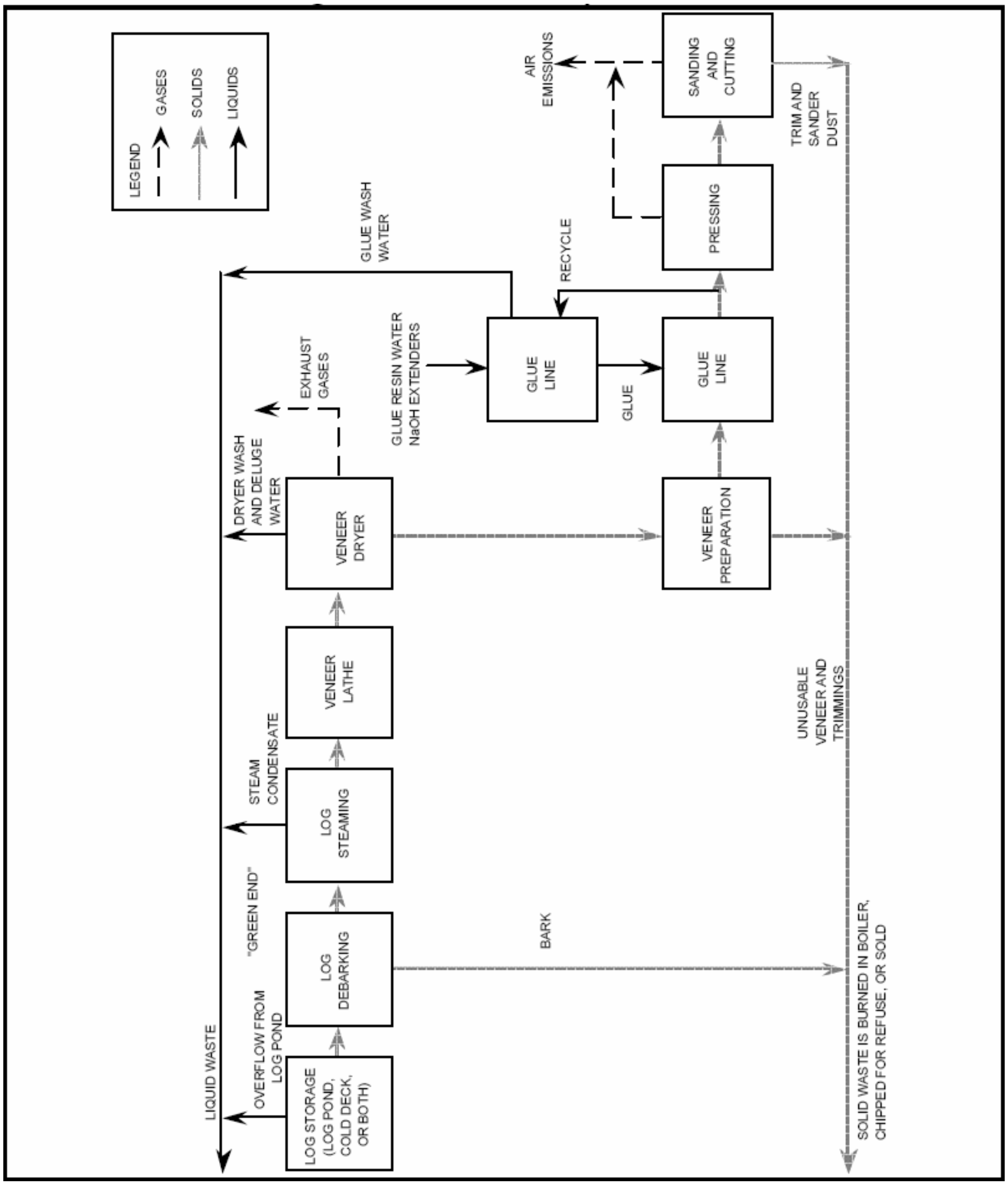

Figure 2-6. Flow Diagram of Veneer and Plywood Production

Source: In U.S. Environmental Protection Agency (EPA). 1995. Profile of the Lumber and Wood Products Industry. As Estimating Chemical Releases from Presswood and Laminated Wood Products Manufacturing, EPA, Office of Pesticides and Toxic Substances, March 1988. EPA Office of Compliance Sector Notebook Project, Office of Enforcement and Compliance Assurance, EPA, Washington, DC. September 1995.

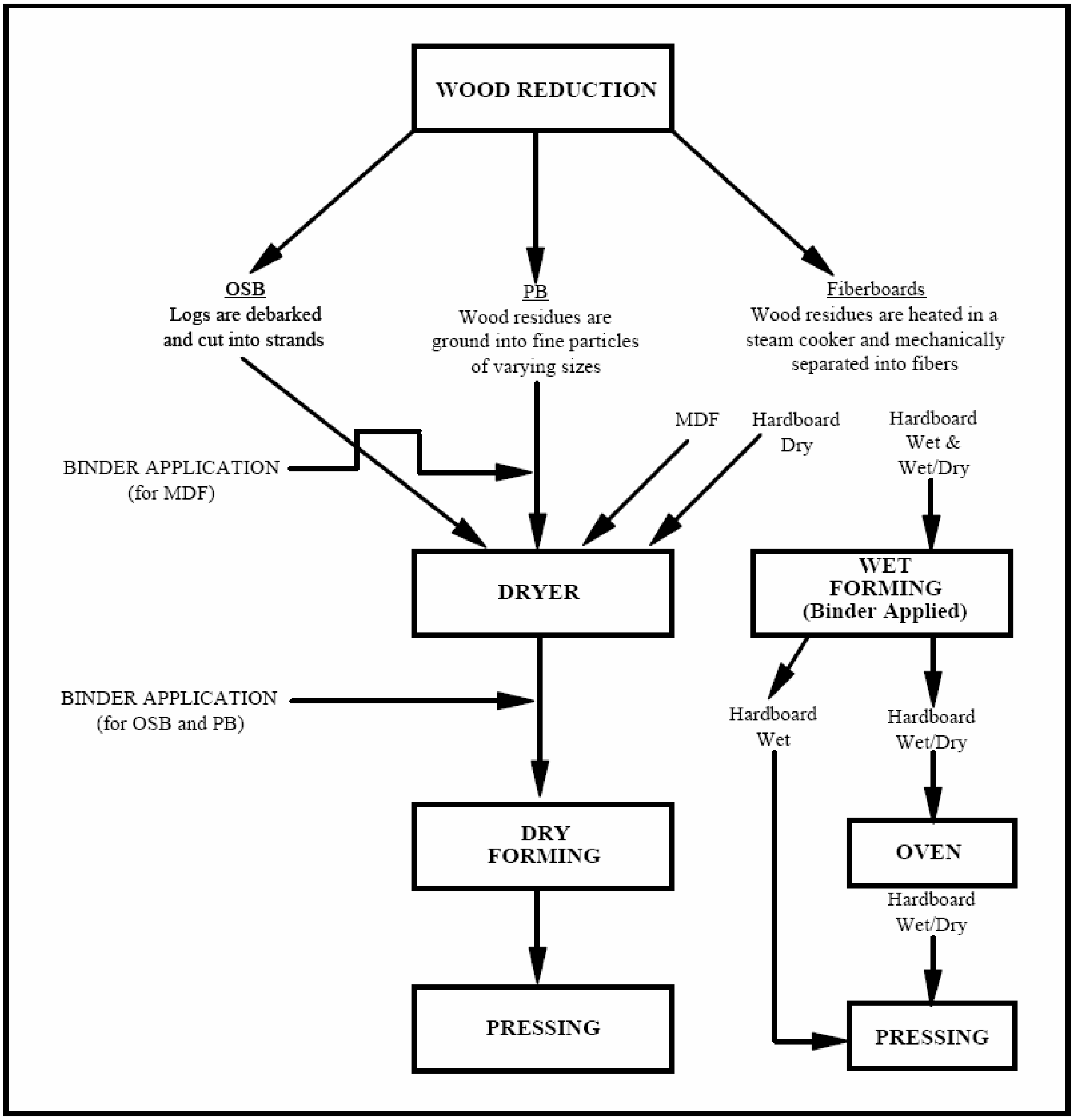

Figure 2-7. Reconstituted Wood Panel Process Flow

Source: In U.S. Environmental Protection Agency (EPA). 1995. Profile of the Lumber and Wood Products Industry. As Characterization of Manufacturing Processes, Emissions, and Pollution Prevention—Options for the Composite Wood Industry; Martin and Northeim, Research Triangle Institute Center for Environmental Analysis, 1995. EPA Office of Compliance Sector Notebook Project, Office of Enforcement and Compliance Assurance, EPA, Washington, DC. September 1995.

2.3 Energy Profile

As described briefly above (and discussed in more detail in Sections 3 and 4), the production processes used to manufacture paper and wood products create significant quantities of biomass waste products. These biomass wastes allow the forest products industry to contribute to overall energy supplies in the United States by self-generating substantial amounts of energy. This subsection discusses the energy profile of the industry as a whole and how biomass fits into its energy mix. Sections 3 and 4 then describe where in the industry's production processes the biomass energy is generated and the technologies used to harness the energy.

Renewables and biomass energy sources play an essential role in the U.S. energy supply. In 2004, renewables supplied more than 6% of all energy used in the country, or 6 quadrillion Btu (10^{15} Btu). As shown in Figure 2-8, biomass provided the largest share of this contribution, having recently displaced hydroelectric sources as the largest renewable energy source.[2] The majority of this biomass energy consumption occurs in the forest products industry (see Figure 2-10). If this industry were to attempt to replace biomass with natural gas, the next largest energy source for the forest products industry, total U.S. demand for natural gas would increase by around 10%.[3]

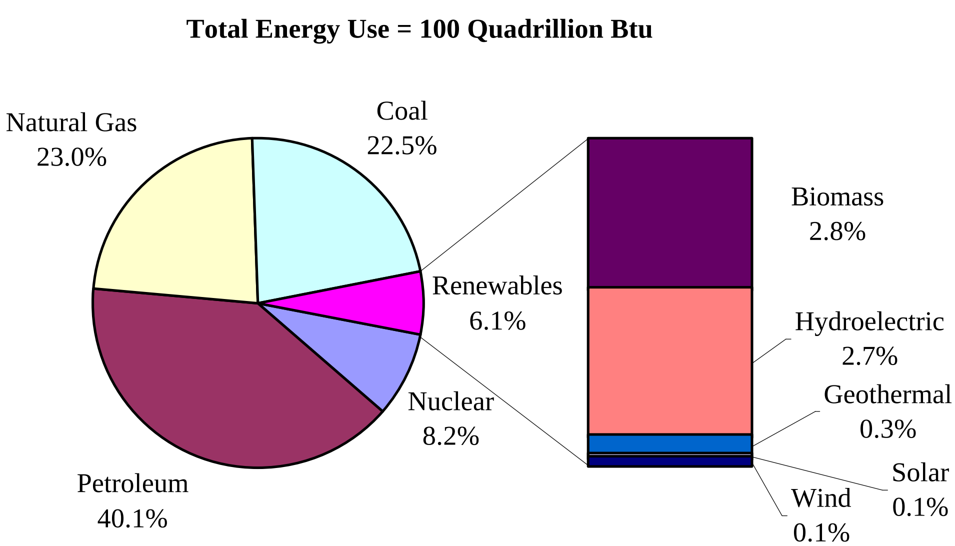

Figure 2-8. Renewables and Biomass in the U.S. Energy Supply in 2004

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2005a. Annual Energy Review 2004. Report No. DOE/EIA-0384(2004). Available at: http://www.eia.doe.gov/emeu/aer/contents.html.

Wood, black liquor, and wood waste represent the largest categories of biomass energy sources. Figure 2-9 illustrates how this biomass use has changed over time. In the industrial sector of the economy, consumption has roughly tripled since 1950, as firms increasingly choose to burn hogged fuel instead of putting it in landfills. Residential use has varied more, depending on technologies used for home heating and the energy crisis of the 1970s, which dramatically increased the prices of fossil fuels and encouraged wood consumption over a short time span.

[2]Since 1989, biomass and hydropower have competed as the largest renewable energy sources. While biomass energy consumption has remained fairly constant, hydropower output varies greatly depending on rainfall.

[3]Approximation based on relative boiler efficiencies for natural gas versus bark and black liquor in steam generation, from EERE (2005).

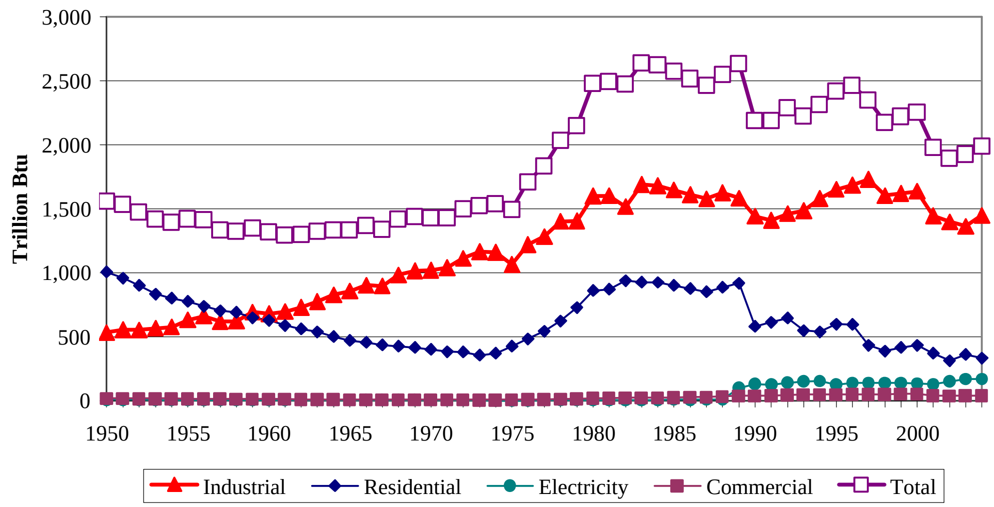

Figure 2-9. Energy from Wood and Black Liquor

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2005a. Annual Energy Review 2004. Report No. DOE/EIA-0384(2004). Available at: http://www.eia.doe.gov/emeu/aer/contents.html.

Across all types of biomass (see Figure 2-10), the paper and allied products industry is responsible for 75% of all industrial biomass energy consumption, using over 1,000 trillion Btu. The lumber and wood products industry is a distant second with around 200 trillion Btu. Biomass use in the agriculture, forestry, and mining industries and the food and kindred products industry is concentrated on agricultural by-products and crop waste, unlike the forest products industry.

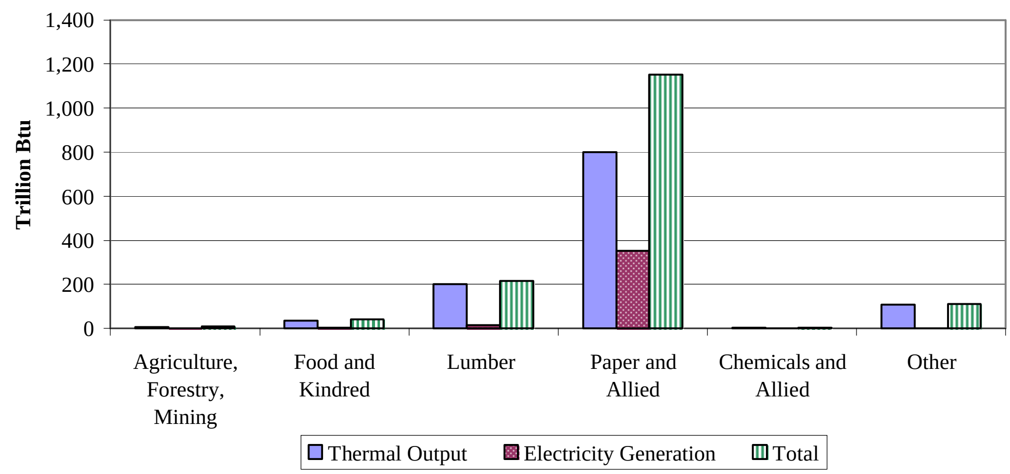

Figure 2-10. Industrial Biomass Energy Use in 2003

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2005b. Renewable Energy Trends 2004. Available at: http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends04.html.

In the paper manufacturing industry, around 70% of the biomass is used to produce steam, needed mainly for paper drying, although it is also used for applications in pulp digesting/refining and starch cooking. Electricity generation is also an important function of the biomass energy, which is used to run equipment such as pumps and fans, especially in kraft pulp mills. In contrast, the lumber and wood products industry generates almost no electricity and focuses on thermal output.

As shown in Figure 2-11, the paper and allied products industry relies on a wide variety of renewable and biomass products to provide this energy. Unlike the lumber and wood products industry, which gets 99.9% of its biomass energy from wood/wood-waste solids, paper manufacturers use wood solids, black liquor, wood-waste liquids, and a range of other types of biomass. Similar to the lumber and wood industry, however, the majority of these sources are related to the production of paper products and are self-generated.

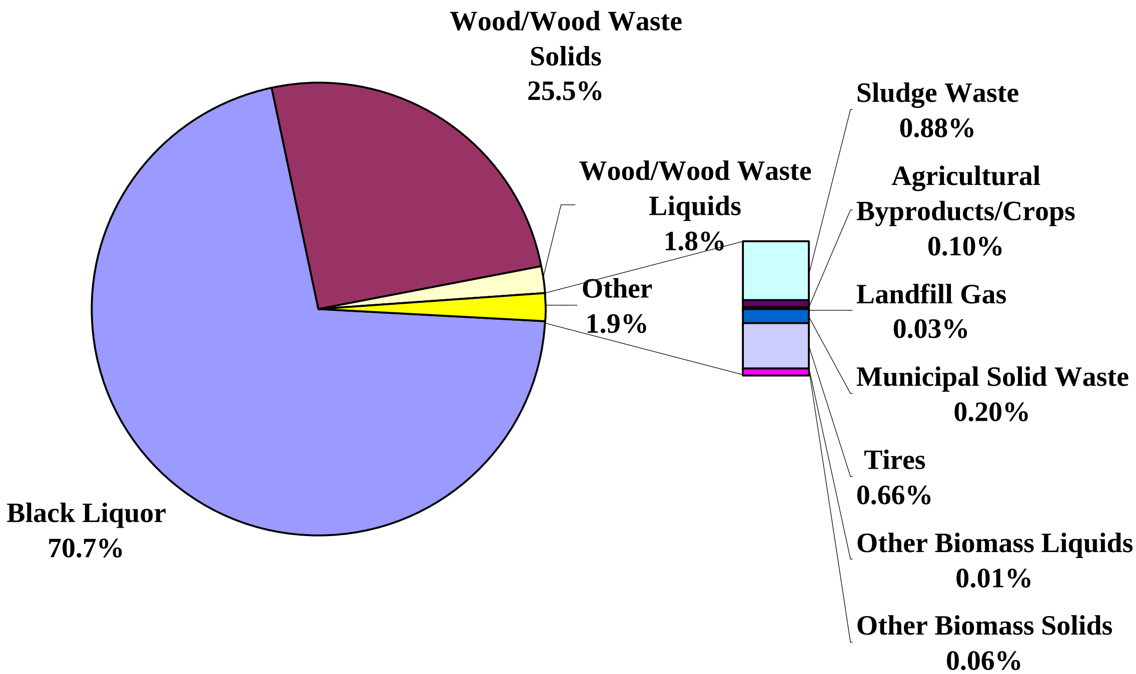

Figure 2-11. Renewable Energy Use in the Paper and Allied Products Industry

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2005b. Renewable Energy Trends 2004. Available at: http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends04.html.

Along with biomass, the paper and allied products industry also uses fossil fuel energy for steam and electricity generation. Between these two sources, paper manufacturing is a very energy-intensive process compared with other industries. Adding fossil fuels to the biomass energy use, the paper and allied products industry consumed 2.4 quadrillion Btu in 2002 (EIA, 2005c). Figure 2-12 compares total energy use per dollar of shipments for different manufacturing

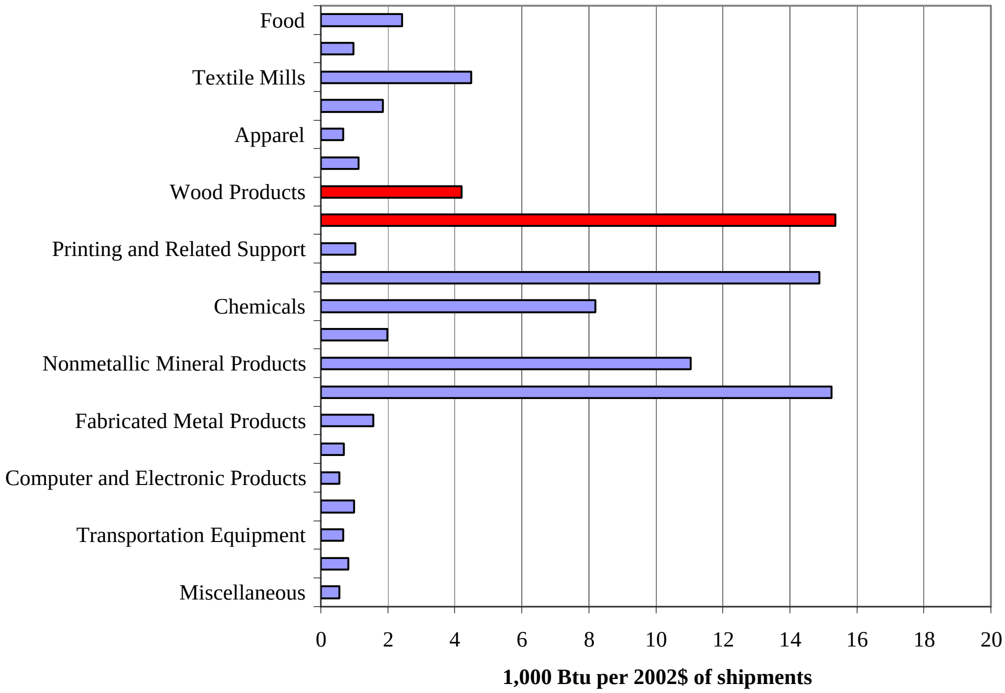

Figure 2-12. Industrial Energy Intensities in 2002 (nonfeedstocks)

Sources: U.S. Department of Energy, Energy Information Administration (EIA). 2005c. Manufacturing Energy Consumption Survey 2002. Available at: http://www.eia.doe.gov/emeu/mecs/; and U.S. Census Bureau (USCB). 2005. 2002 Economic Census Reports: Industry Series. Available at: http://www.census.gov/econ/census02/.

industries (feedstocks are excluded to focus on energy consumption in the manufacturing process; if feedstocks were included, industries such as petroleum and chemicals would be higher than shown). While the lumber and wood products component of the forest products industry is not especially energy intensive, the paper and allied products industry uses as much energy as industries such as petroleum refining, iron and steel, and aluminum manufacturing.

Table 2-6 illustrates the stages within the paper-manufacturing process where this energy is used. Wood preparation, excluding energy in the harvesting and transporting stages, requires relatively little energy, although the machines used in these steps are run by electricity (EERE, 2005a) and considering electricity-generation losses would increase these numbers. Across most types of pulping processes, energy consumption is relatively similar. The kraft process however, which represents the majority of paper manufacturing, generates black-liquor biomass that can be reused to generate steam or electricity. Pulping of recycled paper requires the least energy, but recovered paper mills are dependent on electricity because wood waste and black liquors are not a by-product of their manufacturing processes. Recovery of the chemicals used in the kraft process uses additional energy, mainly to evaporate some of the water contained in the black liquor. Energy used for bleaching can vary significantly across different types of equipment and control systems (EERE, 2005a), but uses around 4 million British thermal units (MMBtu) per ton

Table 2-6. Estimated Energy Use by Process

Process	Average Energy Use (million Btu per ton)	Annual Production (million tons per year)	Total Energy Use (trillion Btu per year)
Wood Preparation	0.45	57.7	26.0
Debarking	0.10	57.7	5.8
Chipping and conveying	0.35	57.7	20.2
Pulping	N/A	91.3	342.2
Chemical pulping	5.05	49.8	251.5
Kraft process	5.04	—	—
Sulfite process	5.38	—	—
Semichemical pulping	6.12	3.3	20.2
Mechanical pulping	6.59	4.5	29.7
Stone ground wood	5.11	—	—
Refiner mechanical pulping	3.10	—	—
Thermo-mechanical pulping	7.09	—	—
Chemi-thermo-mechanical pulping	N/A	—	—
Recycled paper pulping	1.21	33.7	40.8
Kraft Chemical Recovery Process	8.04	53.3	428.5
Evaporation	3.86	53.3	205.7
Recovery boiler[a]	1.13	53.3	60.2
Recausticizing	1.02	53.3	54.4
Calcining	2.03	53.3	108.2
Chemical Pulp Bleaching	4.19	29.9	125.3
Paper and Paperboard Production	6.26	88.4	553.4
Paper refining and screening	0.84	88.4	74.3
Newsprint forming, pressing, finishing	1.44	5.7	8.2
Newsprint drying	4.17	5.7	23.8
Tissue forming, pressing, finishing	1.82	7.0	12.7
Tissue paper drying	7.95	7.0	55.7
Uncoated paper forming, pressing, finishing	1.80	12.3	22.1
Uncoated paper drying	5.10	12.3	62.7
Coated paper forming, pressing, finishing	1.80	8.7	15.7
Coated paper drying	5.30	8.7	46.1
Linerboard forming, pressing, finishing	0.92	20.5	18.9
Linerboard drying	4.05	20.5	83.0

[a]*Does not reflect energy generated in recovery boiler of 4 to 20 million Btu per ton.*

N/A = Not applicable.

Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program (EERE). 2005. Energy and Environmental Profile of the U.S. Pulp and Paper Industry. Prepared by Energetics Corporation. Available at: http://www.eere.doe.gov/industry/forest/pdfs/pulppaper_profile.pdf.

of pulp on average. In the final stage of paper manufacturing, the pulp must be dried after being rolled/pressed into sheets of paper/paperboard. Heat from steam is used to dry the pulp and electricity is used to run the equipment involved in turning the pulp into paper. On average, this is the most energy-intensive step in the manufacturing process.

Specific sources for the energy used in paper manufacturing are shown in Table 2-7 (EERE, 2005a). Over the last 30 years, the mix of biomass versus fossil fuels has shifted significantly in the paper industry. Self-generated sources are now providing close to 60% of the energy needed by the industry, up from only 40% in the early 1970s. This reflects a combination of energy-efficiency improvements, additional recycling of wood fibers, and a focus on reusing chemicals involved in the kraft process. Coal consumption and electricity purchases increased as new equipment has required additional electricity, but natural gas and petroleum purchases have fallen in response to higher prices over time (see Section 6.2). Across all purchases, the total amount of energy purchased has fallen by 25%.

Table 2-7. Sources of Energy in the U.S. Pulp and Paper Industry

	1972		**2000**	
Fuel Type	**Trillion Btu**	**% of Total**	**Trillion Btu**	**% of Total**
Purchased				
Electricity	93.7	4.4%	155.3	7.0%
Steam	22.6	1.1%	33.9	1.5%
Coal	224.7	10.7%	265.8	12.0%
Petroleum	469.4	22.3%	102.2	4.6%
Natural gas	443.9	21.1%	395.6	17.8%
Other[a]	4.3	0.2%	24.1	1.1%
Excess energy sold	–13.1	—	–44.8	—
Total purchased	1,245.5	59.1%	932.0	41.9%
Self-Generated				
Hogged fuel and bark	136.5	6.5%	327.4	14.7%
Black liquor	698.4	33.2%	895.0	40.2%
Hydroelectric	9.2	0.4%	5.0	0.2%
Other	3.0	0.1%	19.9	0.9%
Total self-generated	847.1	40.2%	1,247.2	56.1%
Gross Energy Use[b]	**2,105.7**	**100.0%**	**2,224.1**	**100.0%**

[a] *Includes LPG and other purchased energy.*

[b] *Includes electricity and steam sold to off-site users.*

Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program (EERE). 2005. Energy and Environmental Profile of the U.S. Pulp and Paper Industry. Prepared by Energetics Corporation. Available at: http://www.eere.doe.gov/industry/forest/pdfs/pulppaper_profile.pdf.

Overall, energy consumption across all sources in the pulp and paper industry was only up by 4% between 1972 and 2000, even though paper/paperboard production increased more than 75% (Howard, 2003). Figure 2-13 illustrates how this has translated into energy-efficiency improvements on a per-ton basis over time. From 32 MMBtu per ton of paper in 1972, energy utilization has fallen to around 24 MMBtu per ton, a 24% decrease. The figure also shows how this has been accompanied by the shift from purchased and fossil fuels into self-generated renewable sources.

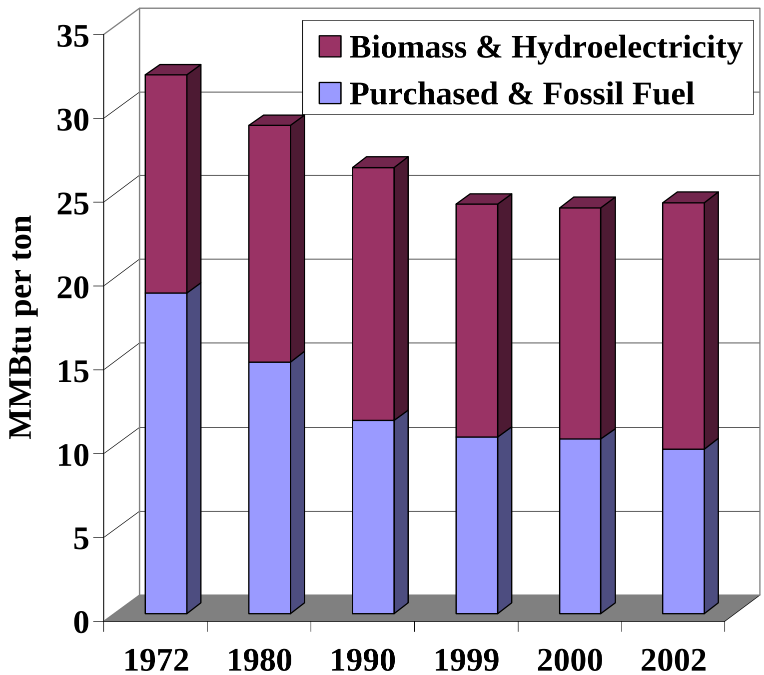

Figure 2-13. Energy Use in Paper Manufacturing

Source: American Forest & Paper Association (AF&PA). 2005. FW: AF&PA Responses to EIA Biomass Questions. E-mail sent December 21, 2005.

3. Current Technologies

This section discusses the current technologies used at forest products facilities to generate heat, steam, and electricity from biomass. Recent trends in technology usage and design that have affected biomass energy consumption are also discussed.

3.1 Pulp and Paper Mill Biomass Energy Technologies

As discussed in Section 2.3, pulp and paper mills use substantial amounts of electricity and steam, and thus, the industry is continually looking for ways to acquire energy more efficiently and to better utilize available fuels. Figure 3-1 shows a typical energy cycle at a kraft pulp mill. Wood residues (e.g., bark) and spent liquor (e.g., black liquor) are the primary sources of biomass fuel at pulp and paper mills. Wood residues are produced on site during the processing of whole logs into chips. Spent pulping liquor is generated during the pulping process and contains both inorganic chemicals added during the pulping process and organic chemicals extracted from the wood. Evaporation of the black liquor is necessary to increase its solids content prior to burning it as a fuel. WWT sludge, which is predominantly composed of wood fiber, is another source of biomass energy, although not all pulp and paper mills burn their WWT sludge. Biomass boilers at pulp and paper mills include chemical recovery furnaces (at mills that practice chemical pulping) and wood-fired boilers. Fossil fuel–fired boilers are also used to generate energy at pulp and paper mills. As shown in Figure 3-1, high-pressure steam from the power boilers and recovery boilers is routed to a turbine, where it is used to generate electricity for the mill. Intermediate-pressure steam (e.g., 160 psig) and low-pressure steam (e.g., 60 psig) are then extracted from the turbine for process use (Boniface, 1992).

3.1.1 Chemical Recovery Furnaces

The chemical recovery furnace is essentially a steam generator that uses spent pulping liquor (e.g., black liquor) as its fuel. The recovery furnace is also the key component of the mill's chemical recovery process. Because spent liquor is a by-product of chemical pulping, recovery furnaces only operate at chemical pulp mills. Although there are approximately 592 U.S. facilities that produce pulp, paper, or both pulp and paper, only 128 of these mills produce chemical pulp (Lockwood-Post, 1999; RTI, 2005; BLRBC, 2005). Table 3-1 shows the current number of chemical pulp mills and recovery furnaces operating in the United States, along with the total capacity of these furnaces. Because kraft pulp mills dominate the industry, the remainder of this discussion of chemical recovery furnaces focuses on kraft recovery furnaces, also referred to as "black liquor recovery boilers."

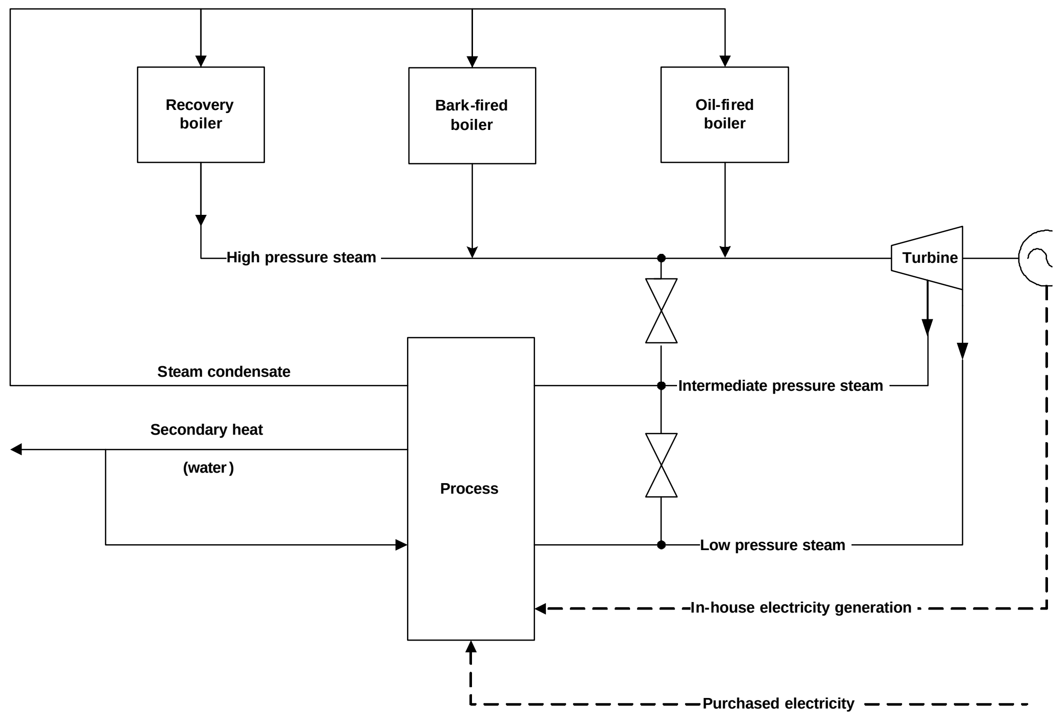

Figure 3-1. Typical Energy System for a Kraft Pulp Mill

Source: Smook, Gary A. 1992b. Mill Services. Chapter 25 in Handbook for Pulp & Paper Technologists. 2nd Edition. Vancouver, BC: Angus Wilde Publications Inc.

Table 3-1. Recovery Furnaces and Spent Liquor Production at U.S. Chemical Pulp Mills

Pulping Process	Number of Pulp Mills	Number of Recovery Furnaces[a]	Spent Liquor Capacity[b]	
			Million Tons Liquor Solids per Year	Trillion Btu per Year
Kraft and soda[c]	111	175	81.3	1,073
Sulfite	7	13	1.6	22
Semichemical[d]	10	12	0.9	12
Total	**128**	**200**	**83.8**	**1,106**

[a]*Includes fluidized-bed reactors, rotary liquor kilns, and other types of chemical recovery combustion units at sulfite and semichemical pulp mills.*

[b]*Assumes all recovery furnaces operate 24 hours a day, 351 days a year, and average Btu value of spent solids is 6,600 Btu per pound.*

[c]*Only one soda process mill (with one recovery furnace) is operating in the United States.*

[d]*Refers to stand-alone semichemical pulp mills; semichemical operations co-located with kraft mills are included in the kraft and soda category.*

Sources: RTI International (RTI). 2005. Pulp & Paper Recovery Furnace Database; and Black Liquor Recovery Boiler Advisory Committee (BLRBAC). 2005. BLRBAC Database. Available at: http://www.blrbac.org. Accessed December 21, 2005.

The first modern recovery furnace, referred to as the Tomlinson recovery furnace, was developed in the 1930s. The Tomlinson recovery furnace is still being used today, although there have been a number of improvements since its inception. One of the most significant improvements from both an environmental and energy efficiency standpoint is the development of the nondirect contact evaporator (NDCE) furnace. Relatively high fuel oil costs in Scandinavia in the 1960s created a need for more thermally efficient recovery furnaces, which led to improvements in black liquor evaporator system designs (i.e., higher solids firing) and the development of the NDCE recovery furnace (also referred to as the "low odor" recovery furnace because of the reduction in total reduced sulfur [TRS] emissions compared with direct contact evaporator [DCE] recovery furnaces) (Smook, 1992a).

The first U.S. installation of an NDCE recovery furnace took place in 1969, and NDCE recovery furnaces soon became the preferred technology for all new recovery furnace installations (EPA, 1996). Figure 3-2 shows a simplified diagram of the NDCE recovery furnace system.

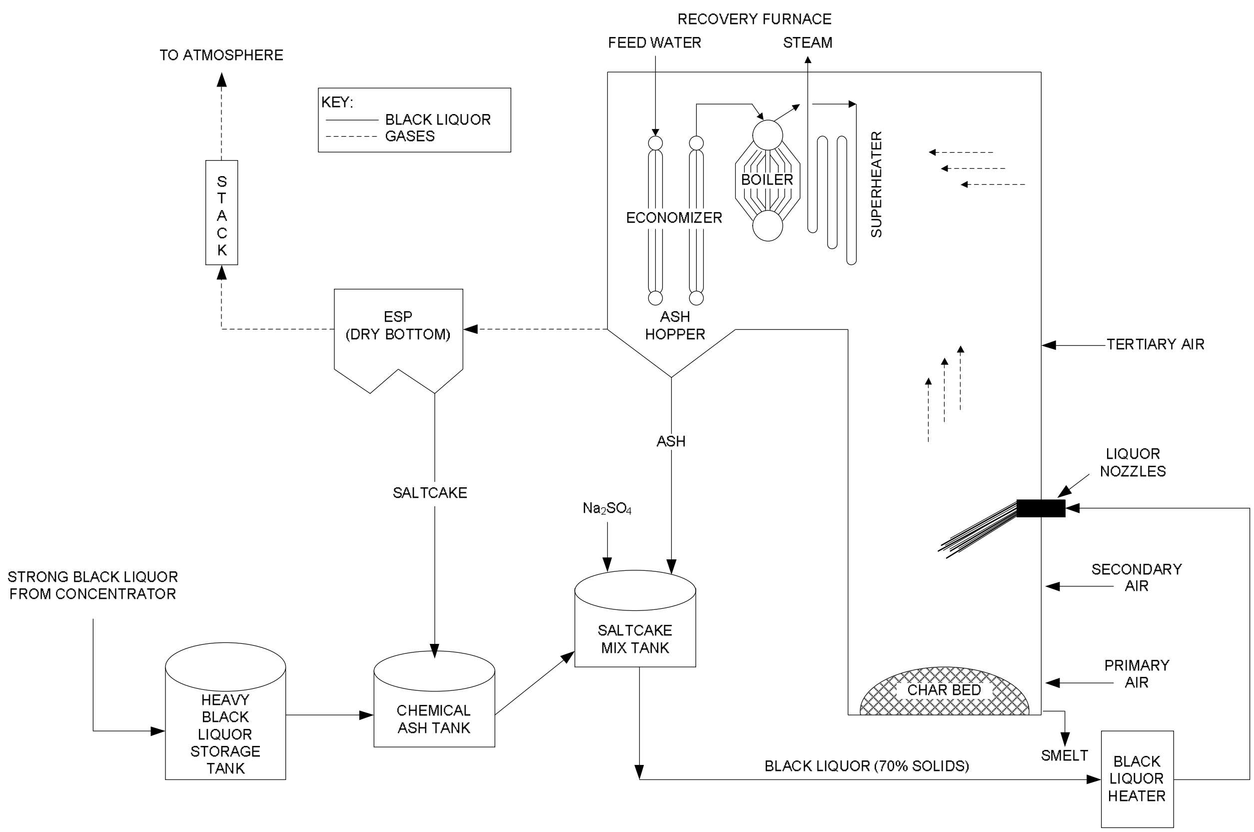

Figure 3-2. NCDE Recovery Furnace System

Concentrated black liquor is sprayed into the furnace through fixed or oscillating nozzles ("guns") mounted in the walls of the recovery furnace. The black liquor enters the furnace as droplets that dry and partially pyrolyze before falling to the char bed in the bottom of the furnace. The inorganic chemicals in the black liquor are recovered via a series of chemical reactions that take place in the furnace, resulting in conversion of sulfate and thiosulfate to sulfide. The sodium sulfide (Na_2S) and other inorganic chemicals drain as molten smelt from the furnace bottom into the smelt dissolving tank (SDT), where reprocessing into pulping liquor continues. The heat generated from the combustion of volatile gases in the recovery furnace is then used to generate steam as the combustion gases are drawn through the heat exchanger section of the furnace (i.e., superheater, boiler bank, and economizer) (EPA, 1996). The recovery furnace typically has a recovered energy efficiency of about 66% and generates steam at 1,250 psig and 900°F at a rate of about 3.5 to 4.0 pounds of steam per pound of black liquor solids (Boniface, 1992).

Figure 3-3 shows the kraft chemical recovery process with the older DCE furnace system. The conversion to the NDCE recovery systems eliminated the DCE (replaced with a high-solids concentrator), as well as black liquor oxidation units, which were installed solely to reduce TRS emissions from the DCE. Other equipment in the recovery furnace system (e.g., SDTs, lime kilns) were not affected. Because DCE recovery furnaces are less efficient and generate more air pollutants per ton of BLS than NDCE recovery furnaces, only one new DCE recovery furnace has been built since 1979, and none have been built since 1988 (EPA, 1996). The current population of kraft recovery furnaces includes 55 DCE recovery furnaces and 119 NDCE recovery furnaces (BLRBC, 2005). From 1996 to 2005, approximately 36% of all existing DCE recovery furnaces (30 out of 83 DCE furnaces total) were (1) shut down as part of mill closures; (2) shut down and replaced with NDCE recovery furnaces; or (3) converted to the NDCE furnace design, generally accompanied by a capacity increase. Approximately 31% of U.S. kraft pulp mills (i.e., 34 out of 110 mills) still operate at least one DCE furnace. Although 32% (55 out of 174) of kraft recovery furnaces are DCE furnaces, these furnaces account for only 23% of black liquor fuel consumption because of their smaller capacities (RTI, 2005).

Although the Tomlinson recovery furnace in its NDCE form has dominated the industry for many years, it still has relatively low thermal efficiency and a low power-output to total-heat-input ratio (Tucker, 2002). Over time, the electric power requirements of pulp and paper mills have increased disproportionately to the steam requirements, as equipment used for pulping and papermaking have become more advanced. For example, a modern paper machine has an electric power load per ton of paper that is 1.5 to 2 times that of an older machine (Tucker, 2002). The rising demand for electricity, combined with other factors, such as an aging population of recovery furnaces, has led to research into alternatives to the traditional Tomlinson recovery furnace. Although a number of alternative technologies have been investigated over the years, the industry is currently focusing its research on BLG and the concept of a forest products biorefinery, as discussed in Section 4.1.

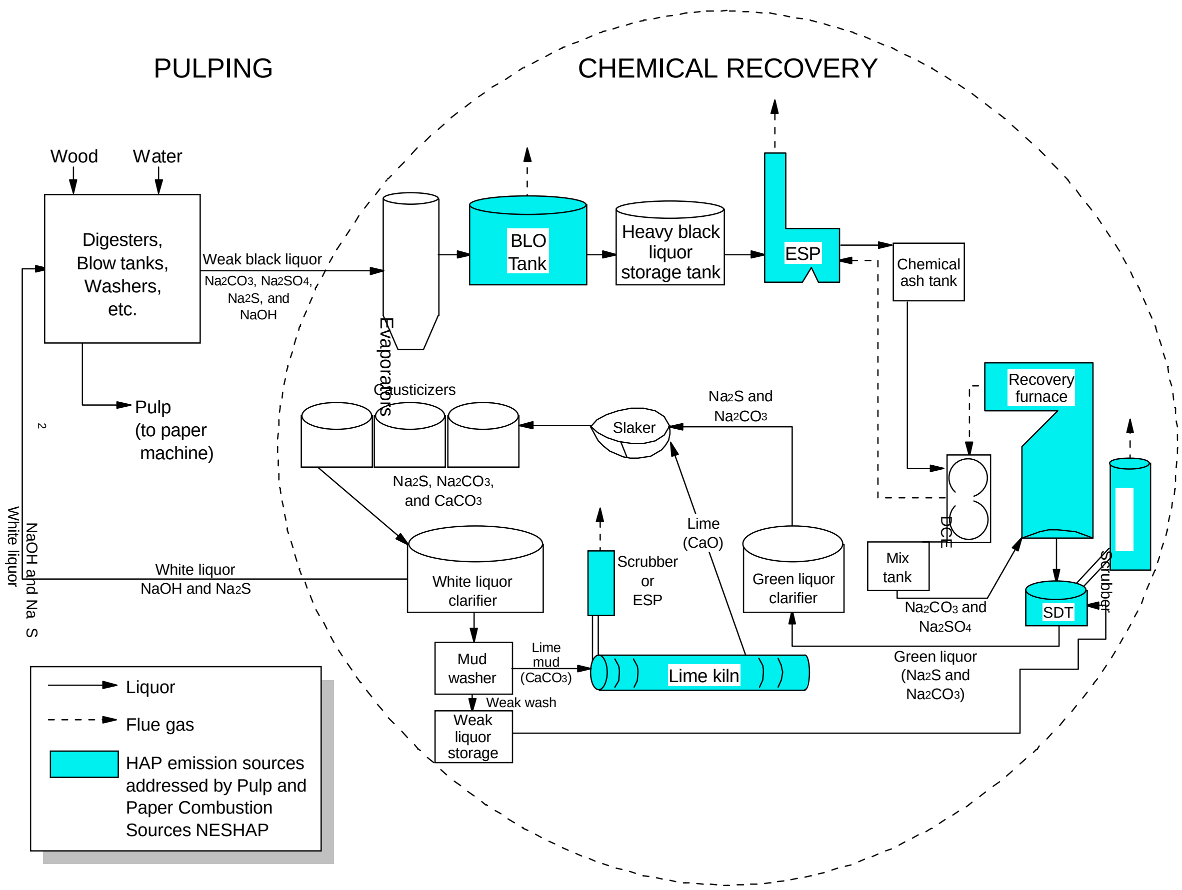

Figure 3-3. Chemical Recovery System with DCE Recovery Furnace

In relating technology changes to changes in black liquor fuel, it is important to note that black liquor fuel consumption is directly tied to virgin pulp production—as virgin pulp production goes up, so does black liquor generation/consumption and vice versa. Although improvements in the recovery furnace efficiency have led to increased steam/energy generation, this had not directly impacted black liquor fuel consumption. Other process improvements such as improvements in pulping yields (e.g., oxygen delignification) and fiber recovery in the papermaking area reduce the ratio of black liquor produced per ton of product, but do not result in an overall decrease in black liquor production unless the quantity of product produced remains flat. Other factors, such as foreign competition that could cause chemical pulp mill closures or production curtailments, would be expected to have a greater impact on black liquor fuel consumption. As discussed in Section 4.1, other emerging technologies, such as BLG and the forest products biorefinery concept, could improve the economic condition of U.S. kraft pulp mills such that black liquor production/consumption would increase in keeping with its increased value as an energy source beyond the mill boundary.

3.1.2 Wood-Fired Boilers

As shown in Table 3-2, there are more than 2,800 wood-fired boilers at forest products facilities, including an estimated 386 at pulp and paper facilities. Wood-fired boilers at pulp and paper mills are significantly larger than those operated by other forest products facilities and are an important source of energy for the pulp and paper operations.

Table 3-2. Capacity and Age Data for Wood-Fired Boilers at Forest Products Facilities

Parameter	Pulp and Paper Mills	Lumber Mills and Wood Products Facilities	Wood Furniture Facilities	Total
Estimated number of wood-fired boilers[a]	386	> 1,845	610	2,841+
Average capacity (range), MMBtu/hr	506 (10–1,300)	45 (1–1,200)	21 (0.8–70)	—
Average age (range), years[b]	57 (9–75)	30 (8–99)	38 (8–97)	—

[a] *The exact number of wood-fired boilers is not known. Although it is expected that most of the larger boilers and boilers at larger facilities are accounted for in the referenced data sources, some small boilers or boilers at small facilities may not be represented.*

[b] *Based on original installation date; does not account for major modifications.*

Sources: U.S. Environmental Protection Agency (EPA). 1997. Industrial Boilers Database; U.S. Environmental Protection Agency (EPA). 1999. National Emissions Inventory Database; U.S. Environmental Protection Agency (EPA). 2005. Plywood and Composite Wood Products (PCWP) Database; and U.S. Department of Energy, Energy Information Administration (EIA). 2005g. Biomass Boiler Database.

Most pulp and paper mills operate conventional wood-fired boilers (e.g., a spreader stoker), where the biomass is combusted in a furnace chamber and the resultant heat is used to generate steam inside water tubes (NCASI, 2003). Wood-fired boilers generally are capable of cofiring one or more fossil fuels. Very few boilers at pulp and paper mills exclusively fire wood residues (NCASI, 2003).

Rising fossil fuel costs in the 1970s led to better utilization of bark and other on-site wood wastes (collectively referred to as “hog fuel”) as an energy source at pulp and paper mills. Prior to the 1970s, hog fuel was often landfilled (Smook, 1992b). The major issue with burning hog fuel is its high moisture content, which reduces its heating value (and thus reduces its steam-generating potential). As hog fuel became viewed more as a resource than as a waste, pulp and paper mills began looking at methods such as mechanical dewatering using double-nip roll presses to reduce its moisture content. More recently, mills have begun using the boiler exhaust gases to dry the incoming hog fuel as part of an integrated system (Smook, 1992b).

Burning sludge from the mill’s WWT system is also a fairly recent trend. In 1979, only about 10% of WWT sludge was burned; by 1995, that percentage had more than doubled to about 25%

(NCASI, 1999). As with the hog fuel, high moisture content is an issue, and sludge dewatering technologies and methods have advanced to address this issue. Sludge dewatering technologies include vacuum filters, belt filter presses, and screw presses, where screw presses are able to achieve the driest sludge. Because of its superior performance and the increase in sludge burning, the percentage of pulp mills using screw presses nearly doubled from 17% to 30% during the 1988 to 1995 time period (NCASI, 1999).

Not only is more WWT sludge being used as fuel, but the overall quantity of sludge generated at pulp and paper mills has increased, with a 26% increase just from 1988 to 1995 (NCASI, 1999). The industry attributes this increase to a 17% increase in manufacturing during the period, as well as increased use of recycled (i.e., lower yield) fiber across the industry (NCASI, 1999).

Along with the improvements in technologies for dewatering hog fuel and sludge came improvements in boiler design and solid fuel handling systems to allow for more efficient burning of these lower-quality fuels. A few mills also began installing fluidized bed boilers. Although only a small number of paper mills currently operate fluidized bed boilers, the number of these units is increasing because of their efficiency in combusting solid fuel mixtures with lower heating values such as wet wood residues and WWT sludge (NCASI, 2003).

As discussed in Section 6.1, there are a large number of older boilers that are due for replacement. As these older boilers are replaced with new units, increases in biomass consumption are expected because many of the newer units, particularly fluidized bed units, can more efficiently burn the wood wastes and sludge. Thus, more mills are likely to choose to burn a portion of their sludge along with their waste wood.

3.2 Lumber and Wood Products Facilities Biomass Energy Technologies

As shown previously in Table 3-2, wood-fired boilers at lumber mills, wood products facilities, and wood furniture plants are significantly smaller than the wood-fired boilers used at pulp and paper mills, with average capacities between 21 and 45 MMBtu per hour as compared with 506 MMBtu per hour for pulp and paper mill boilers. Biomass fuels at these facilities include bark, sawdust, planer shavings, sanderdust, and other wood fuels. Most of the biomass boilers at lumber mills and wood products plants are based on conventional boiler technology (e.g., spreader stokers, dutch ovens). However, a significant number of these lumber and wood products facilities use fuel cells for process heating, especially at newer wood products facilities. Lumber kilns and rotary wood particle dryers are often direct-fired units that use fuel-cell burners to provide heat for the drying process. At other facilities, a wood-fired boiler may be used to generate steam for indirect heating of the dryers and kilns (e.g., steam-heated veneer dryers and steam-heated lumber kilns).

Recent trends in the wood products industry include the installation of integrated dryer/energy systems, whereby the dryer exhaust gases are routed back to the biomass combustion unit (e.g., as combustion air) in a closed-loop system. These systems fall into two groups: one group uses fuel-cell technology for the biomass combustion unit, while the other group uses wood gasifiers. These systems began emerging in the 1990s, primarily as a more energy-efficient and cost-effective way for new wood products facilities to respond to environmental regulations, which required that volatile organic compounds (VOC) emitted from the dryer exhaust gases be controlled. Existing wood products facilities faced with the same environmental requirements could not easily reconfigure their combustion units and drying systems to achieve these closed-loop systems. Thus, the majority of the existing affected facilities installed regenerative thermal oxidizers (RTOs), which use natural gas as fuel and function only as emission control devices. Because the closed-loop dryer/energy systems use wood as their fuel, installation of these systems at new facilities could potentially increase the need for and consumption of biomass at these facilities. Another recent trend affecting the use of biomass consumption at lumber and wood products facilities is the increase in lumber mills that use biomass boilers for generating electricity, in addition to producing steam for the on-site lumber kilns. The closed-loop dryer/energy systems and cogeneration units at lumber mills are discussed in more detail in Sections 4.3 and 4.4, respectively.

4. New Technologies

This section discusses technologies that are expected to affect future biomass energy consumption in the forest products industry, including

- black liquor and biomass combined cycle gasification,
- fluidized bed biomass boilers,
- closed-loop drying and energy systems at wood products facilities, and
- cogeneration systems at lumber mills.

4.1 Black Liquor Gasification and Integrated Forest Products Biorefinery

BLG systems are under active commercial development in the United States and Europe as potential replacements for Tomlinson recovery furnaces at chemical pulp mills. The driving forces that have led the industry to BLG include

- aging chemical recovery equipment,
- a need for incremental pulp production capacity at existing pulp mills,
- changes in mill energy demands (i.e., more electricity and less steam),
- more stringent emissions regulations, and
- safety (i.e., to eliminate the risk of smelt-water explosions) (Dickinson et al., 1998; Dahlquist et al., 2005).

BLG technology uses heat to convert the organic compounds in black liquor to a hydrogen-rich synthetic gas (syngas), leaving the residual pulping chemicals (primarily sodium carbonate [Na_2CO_3]) for reuse. The syngas can be used to power the gasification unit, and the rest can be fired in a gas turbine, with the exhaust used to raise steam that can be passed through a steam turbine to generate additional electric power, displacing fossil fuels such as natural gas or coal. This overall process is sometimes referred to as the BLGCC process. In addition to generating electric power, the syngas can be converted to supply a variety of fuel and commodity chemical markets, including but not limited to Fischer Tropsch (F-T) liquids to be refined to motor gasoline, distillate fuel, and/or waxes; ethanol; methanol; dimethylether (DME) to produce diesel or LPG; mixed alcohols to ethanol; synthetic natural gas; hydrogen; and/or ammonia. The benefits of BLG relative to conventional technology are expected to include increased efficiency in energy conversion and chemical recovery, reduction/elimination of the smelt-water explosion hazard, reduced maintenance costs, creation of syngas conversion products, and lower emissions of pollutants such as PM, hazardous air pollutants (HAP), sulfur dioxide (SO_2), carbon monoxide

(CO), CO_2, VOC, nitrogen oxides (NO_X), and TRS (EPA, 2001a; G-P, 1999a, 2002; AF&PA, 2005b).

Biomass gasification systems for generating power at pulp mills are also under development. Biomass gasification would produce a synthetic gas fuel from the gasification of wood residuals and pulp mill sludges, which can then be used to replace the fossil fuels currently burned in power boilers. Black liquor and BGCC technologies are the core technologies for industry's IFPB concept. As discussed in the following sections, when combined under the IFPB, these technologies offer mills the potential to more than double the electricity generation from captive self-generated fuels (Tucker, 2002).

4.1.1 Gasification Demonstration Projects

In AF&PA's Agenda 2020, gasification was identified as one of its high-priority research areas. Through the Agenda 2020 process, gasification demonstration projects were undertaken at three facilities, as shown in Table 4-1. These three projects have been completed and are awaiting commercialization throughout the industry, pending the outcome of current economic feasibility studies (G-P, 2002; AF&PA, 2005b, 1998a, 1998b).

Table 4-1. Agenda 2020 Completed Demonstration Projects

Gasification Technology	Plant Name, Location	Application and Description
Kvaerner Chemrec/Air Products	International Paper, Courtland, AL	Applied to kraft black liquor; uses an oxygen-based, high-temperature, pressurized process
Manufacturing and Technology Conversion International, Inc. (MTCI)/StoneChem	Georgia-Pacific, Big Island, VA	Applied to spent semichemical liquor (nonsulfur); uses a pulse-enhanced, steam-reformer process
Battelle/FERCO low-inlet velocity gasification	Weyerhaeuer Co., New Bern, NC, in coordination with McNeil Power Station in Burlington, VT	Applied to wood residuals and pulp mill sludges; uses an air-based, low-temperature, atmospheric process

Sources: American Forest & Paper Association. (AF&PA). 1998a. Industry Gasification Combined Cycle Initiative: Executive Briefing Document. May 1, 1998; and American Forest & Paper Association. (AF&PA). 1998b. Gasification of Kraft Black Liquor, Semichemical Caustic-carbonate Liquor, and Biomass for MACT II and ICCR Compliance.

Figure 4-1 is a diagram of the gasification process (MTCI/StoneChem used at the Georgia-Pacific semichemical mill. The MTCI/StoneChem gasification process uses indirect heating of a bed of Na_2CO_3 solids kept fluid with steam. Black liquor is sprayed into the bed and the liquor droplets uniformly coat the bed solids. This results in high rates of heating, pyrolysis, and steam reforming. Because of the relatively low temperatures (as compared with Tomlinson recovery furnaces), there is no black liquor combustion or smelt formation. Instead, the steam reacts with the black liquor to produce a medium-Btu gas, rich in hydrogen. The product gas passes through

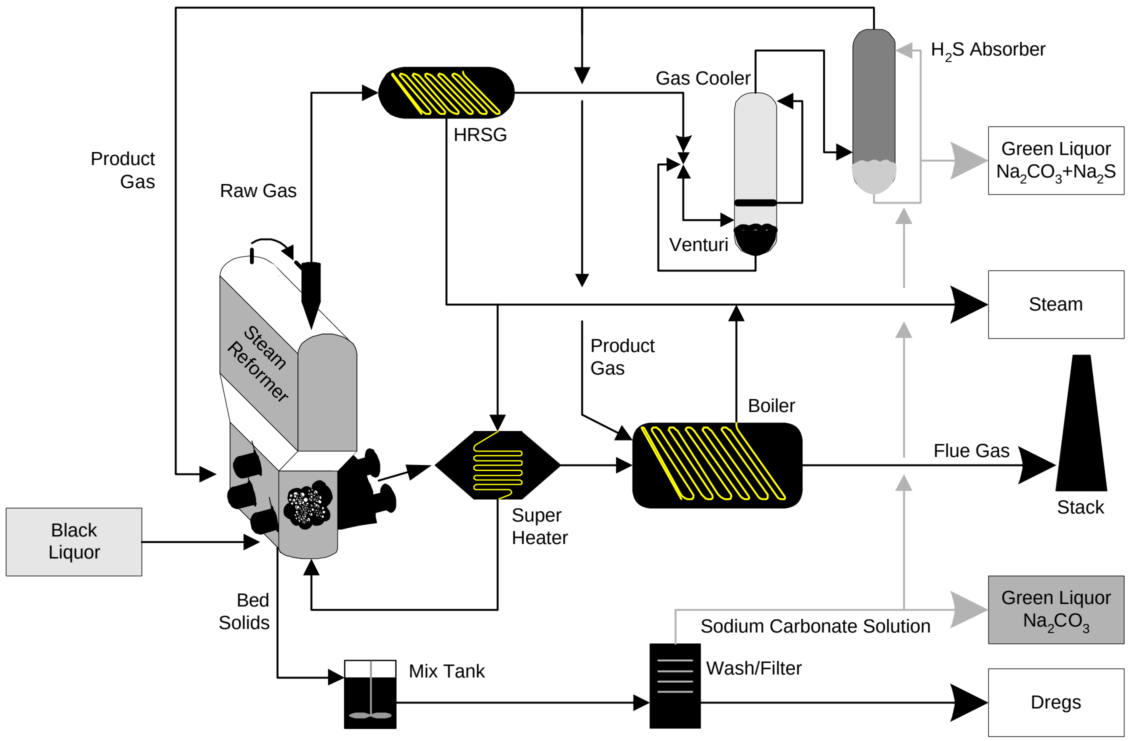

Figure 4-1. BLG System for Georgia-Pacific Big Island Pulp and Paper Mill

Source: Georgia-Pacific Corp. and MTCI/StoneChem, Inc. (G-P). 1999b. Steam-Reforming Gasification Process. Fact Sheet—Proposed Demonstration Project.

a particulate removal device and is then processed through a heat recovery unit to produce steam. The gas is then further cooled and cleaned to recover additional chemicals to produce a clean-burning fuel. Steam produced from the excess product gas burned in the heat recovery unit will replace a portion of the steam being generated using natural gas (G-P, 1999b).

4.1.2 Potential Energy, Environmental and Cost Impacts

Although no rollout schedule for the entire industry has yet been developed, three factors are converging to create a window of opportunity for the commercialization of gasification technology. First, the scientific community and suppliers have brought the technology to the point where large-scale demonstrations are possible. Second, the capital replacement cycle of the industry is about to focus on significant rebuilds or replacement of the powerhouse infrastructure. Finally, the current world emphasis on global climate change may provide significant additional incentives for using this technology, which can potentially reduce GHG emissions (AF&PA, 1998a). Table 4-2 provides a summary of some of the potential national benefits of BLGCC commercialization (AF&PA, 2004). Figures 4-2 and 4-3 show current product and energy outputs using conventional technologies and the potential product and energy outputs following implementation of the IFPB (Farmer, 2004).

Table 4-2. Prospective National Benefits of BLGCC Commercialization

Economic Benefits	• Higher pulp yields (from pulping modifications enabled by BLGCC) reduce pulpwood requirements by approximately 7% per-unit-paper output • Up to $6.5 billion (constant 2002$) in cumulative energy cost savings over 25 years. • Over 25 years, additional potential cumulative emissions credit values in the range of $450 million for SO_2, $3.2 billion for NO_x, and $3.1 billion for CO_2 • Job preservation and growth in the pulp and paper industry
Environmental Benefits	• Higher pulp yields reduce pulpwood requirements by approximately 7% per-unit output • Potential for reduced cooling water and makeup water requirements, for the mill-scale BLGCC. All BLGCC options also result in reduced cooling water and makeup water requirements for the grid power displaced, and they reduce solid waste production at grid power plants • Up to 35 million tons net CO_2, 160,000 tons net SO_2, and 100,000 tons net NO_x displaced annually within 25 years of introduction; additional reductions of particulates, VOCs and TRS • Additional benefits could accrue if BLGCC helps catalyze a new biomass-based energy industry, resulting in the development and use of sustainable biomass supplies for additional energy and chemicals productions
Security Benefits	• Up to 156 billion kilowatt-hours (kWh) more electricity produced compared with continued use of Tomlinson technology within 25 years of introduction; of this, as much as 62 billion kWh would be renewable • Up to 360 trillion Btu per year of fossil energy savings within 25 years of introduction • Potential for fuels and chemicals production from black liquor and other biomass feedstocks directly displacing petroleum
Knowledge Benefits	• Advances in materials science, syngas clean-up technology, alternative pulping chemistries, and other areas

Source: American Forest & Paper Association. (AF&PA). 2004. Agenda 2020—Emerging Technologies & Options for Environmental Performance. Presented by Richard Campbell, AF&PA, at the Discussion of Future Vision for the Forest Products Industry and Options for Environmental Performance Models. Sponsored by U.S. Environmental Protection Agency and AF&PA. Washington, DC. September 22, 2004.

A combination of biomass gasification and BLG in a combined cycle configuration (BGCC and BLGCC) is expected to increase net power output substantially in comparison with a conventional system. For example, at a 1,500-ton-per-day kraft mill, replacing a conventional recovery furnace with a gasification system increases potential power generation from about 70 megawatts (MW) to nearly 200 MW with just a BLGCC system, and to 300 MW with BGCC and BLGCC combined (G-P, 2002; AF&PA, 1998a, 1998b; Tucker, 2002).

The capital costs of a BLG system (including the gasification, biomass boiler, and combined cycle islands) are comparable to the capital costs of conventional technology. For example, at a 1,300-ton-per-day kraft mill, the capital cost of an air-based BLGCC system is about $117 million, while the capital cost of a conventional recovery furnace is about $110 million (in 2000$). While operation and maintenance costs for gasification may be higher than a

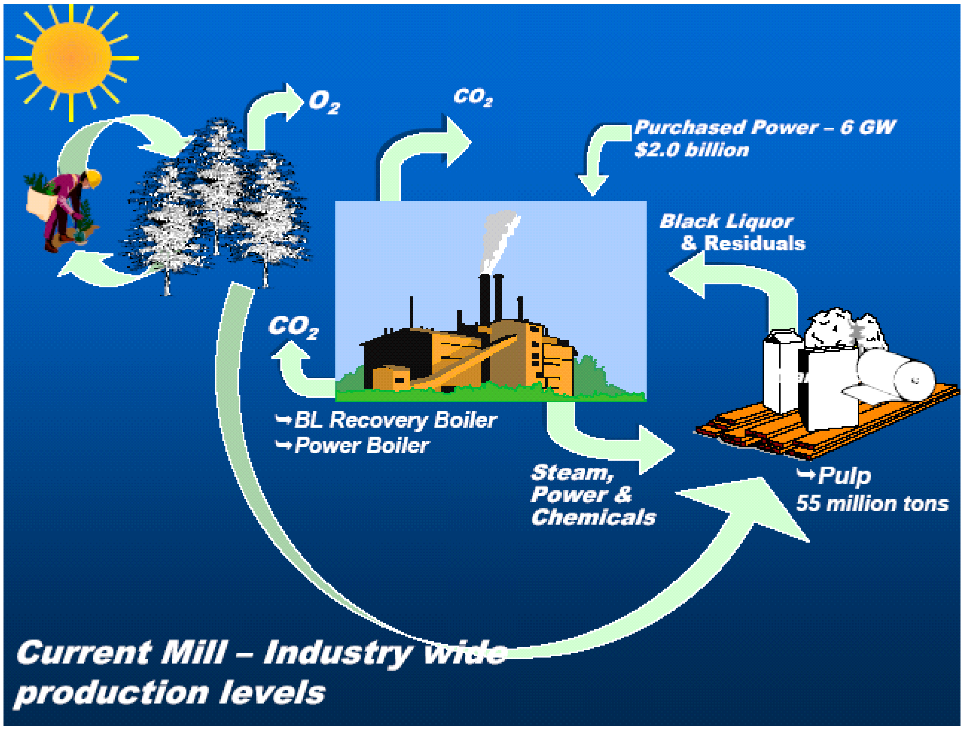

Figure 4-2. Current Mill—Industry-Wide Production Levels

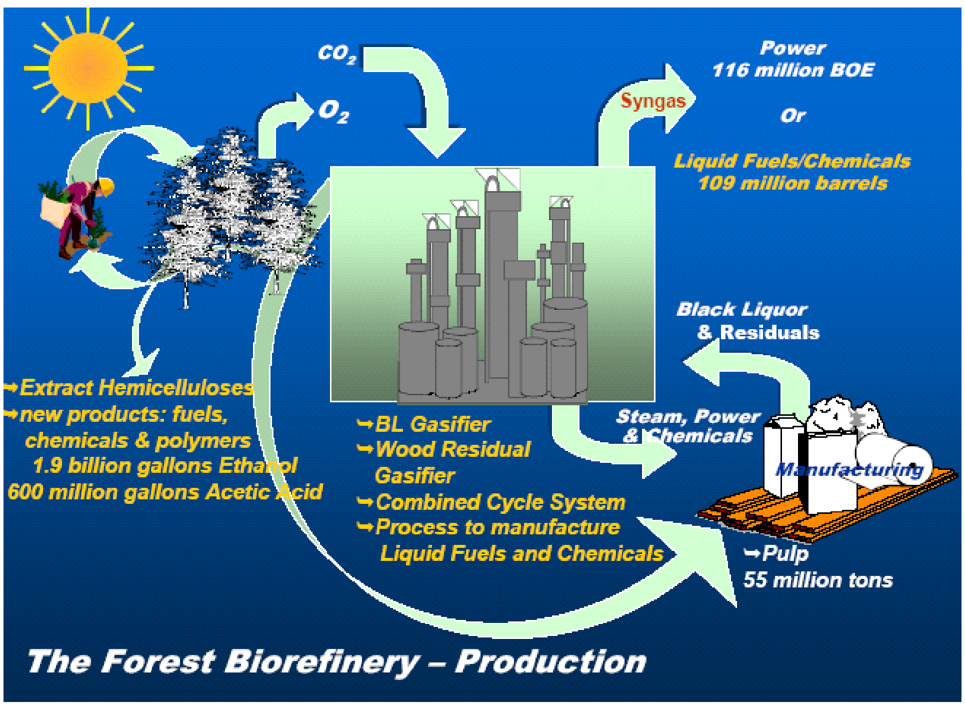

Figure 4-3. The Forest Biorefinery—Production Levels

conventional Tomlinson Recovery Furnace system ($16.9 million versus $6.3 million), the operating credits (i.e., savings from increased power generation) for gasification are also higher ($32.4 million versus $11.9 million), resulting in greater net operating credits for gasification ($15.5 million versus $5.6 million). Mills using gasification technology could use the output from the BLGCC system to displace fossil fuel use at the mill and/or export power to the grid (CV, 2001).

If they prove to be economically and commercially viable for the entire industry, biomass and BLGCC technologies could make substantial reductions in GHG emissions compared with conventional technology. For example, at a 1,300-ton-per-day kraft mill, replacing a conventional recovery furnace with a BLGCC system could decrease CO_2 emissions by 74,000 to 145,000 tons per year, depending on whether the fossil fuel displaced is natural gas or coal. If both the biomass boiler and recovery furnace are replaced with a BGCC/BLGCC system, then CO_2 emissions could be reduced by 122,000 to 239,000 tons per year, depending on the fossil fuel displaced (natural gas or coal). Nationwide, CO_2 emissions could be reduced by 8 to 15 million tons per year by replacing a conventional recovery furnace with a BLGCC system, and 13 to 25 million tons per year by replacing both the biomass boiler and recovery furnace with a BGCC/BLGCC system (depending on whether the fossil fuel displaced is natural gas or coal). (These nationwide reductions could range even higher—up to 60 million tons per year—based on estimates cited in a 2002 industry engineering study.) When gasification is combined with electricity generation, emission reductions could be obtained for PM, HAP, SO_2, CO, VOC, NO_X, and TRS (with hydrogen sulfide [H_2S] scrubbing or recycling). By displacing nonrenewable fossil fuels, these gasification technologies could also reduce fossil fuel consumption, as well as increased efficiencies in energy conversion and chemical recovery compared with conventional technology (EPA, 2001a; G-P, 1999a, 2002; Larson et al., 1998).

4.1.3 Ongoing Research

Although successful implementation of BLG and the forest products biorefinery concept could transform the pulp and paper industry, there are still technical barriers that must be overcome before these technologies can significantly penetrate the kraft pulping sector. Therefore, the industry participates in ongoing, collaborative research projects aimed at addressing gaps in the technology to help accelerate the implementation of BLG and move the industry closer to the goal of the forest products biorefinery. Examples of these research projects include integrating BLG with minisulfide sulfite anthraquinone pulping (to improve pulp yields and thereby reduce energy consumption) and combining BLG with direct causticizing (to eliminate the lime kiln from the chemical recovery process and thereby reduce energy consumption) (EERE, 2005b).

Studies are also underway at Princeton University to assess the economic feasibility of using the syngas produced in the gasification process to produce liquid fuels and chemicals. Preliminary results of this study should be available in the first or second quarter of 2006 (AF&PA, 2005b). The technologies for converting syngas to fuels or chemicals are in various stages of development. Steam reforming of syngas to produce mixed alcohols and ethanol appears to be an opportunity in the short term, with production of methanol, DME, and separation of hydrogen representing medium- to long-term opportunities (AF&PA, 2005b).

The industry also continues to conduct research in other areas of the manufacturing process that will result in incremental energy savings. For example, the dryer section of the paper machine is one of the most energy-intensive steps in the papermaking process, and therefore, the industry is working on the development of a new, more efficient press technology that may reduce energy requirements in the dryers by more than 30% (EERE, 2005b). However, the effects of this type of incremental energy savings on biomass fuel consumption will be very site-specific, with some mills choosing to maintain their biomass fuel consumption rate while reducing fossil fuel consumption, and others choosing to do the reverse. Thus, implementation of BLG and other factors, such as the cost and availability of fossil fuels, are expected to have a more direct impact on biomass fuel consumption than incremental reductions in process energy requirements.

4.2 Fluidized Bed Boilers

As discussed in Section 3.1, an increasing number of pulp and paper mills are installing new fluidized bed biomass boilers (e.g., bubbling bed and circulating bed boilers) or converting existing conventional boilers to fluidized bed designs because of their efficiency in converting lower-quality (i.e., high moisture) biomass fuels such as wet bark and WWT sludge into energy. In a conventional boiler, firing of supporting fossil fuels is needed if the moisture content of the biomass is greater than 50% to 55%. However, a fluidized bed boiler can fire biomass at moisture contents up to 60% to 65% without supporting fuels. This 10% difference makes a fluidized bed very economical compared with a conventional boiler in cases where high-moisture fuels are used (Proznik et al., 1993).

Other advantages of fluidized beds over conventional boilers include

- fuel flexibility,
- extension of the life expectancy of on-site landfills by using sludge as fuel and thereby reducing the amount of sludge entering the landfill,
- reduced maintenance costs,
- reduced flue gas emissions (CO, VOC, NO_x), and
- reduced fossil fuel usage (and thus, reduced GHG emissions) (Charlson, 1999; Proznik et al., 1993).

The trend toward increasing numbers of fluidized bed biomass units at pulp and paper mills is expected to continue. Therefore, the consumption of biomass in the form of waste wood and sludge should also continue to increase as pulp and paper mills continue to better utilize self-generated fuels. Wood gasification is expected to trail BLG in terms of implementation, so pulp and paper mills are expected to continue to move toward fluidized bed boilers even as gasification research continues. Both technologies favor the use of waste wood and sludge as fuel, so biomass consumption is expected to increase regardless of the penetration of each technology.

One factor that could negatively impact installation of new biomass boilers is a drop in natural gas prices, although such a drop is not anticipated. Because the capital cost of a natural gas boiler is about one-third of the cost of a conventional biomass boiler (biomass boilers have added costs of pollution control devices and specialized stokers) and one-fourth to one-fifth the capital cost of a fluidized-bed boiler, mills have installed natural gas boilers rather than biomass boilers during periods when natural gas prices were relatively low (Weyerhaeuser, 2005).

4.3 Closed-Loop Energy Systems at Wood Products Facilities

Environmental regulations in the 1990s, and the cost of natural gas for operating incineration-based emissions control systems (i.e., RTOs) at wood products plants, have been a major factor in driving a number of newer wood products facilities to install biomass-based energy systems such as the Wellons dryer energy and thermal oxidation (DETOX) system and the Callidus closed-loop gasification system (CLGS), which serve dual roles as both energy generators and pollution control devices. In these systems, exhaust gases from the dryers are routed to the combustion or gasification system as combustion air, and then the combustion unit or gasification system provides hot air back to the dryers in a closed-loop system. Installation of these systems can either eliminate the need for RTOs or reduce the number of RTOs required to meet U.S. Environmental Protection Agency (EPA) emission limits, depending on the facility and system installed.

4.3.1 Facility Descriptions

The two different types of closed-loop biomass energy systems that are currently in use at wood products facilities for heating and emissions control are described below.

Wellons DETOX System. Figure 4-4 shows a simplified example of an energy/drying system at an OSB wood products facility. The Wellons system begins with the burner, which combusts wood fuel in the presence of dryer exhaust gases. A portion of the hot exhaust from the burner heats the oil used by the press. The remaining hot burner exhaust enters the hot side inlet to the air heater. Ambient air is heated inside the air heater and passed through the wood flake dryers.

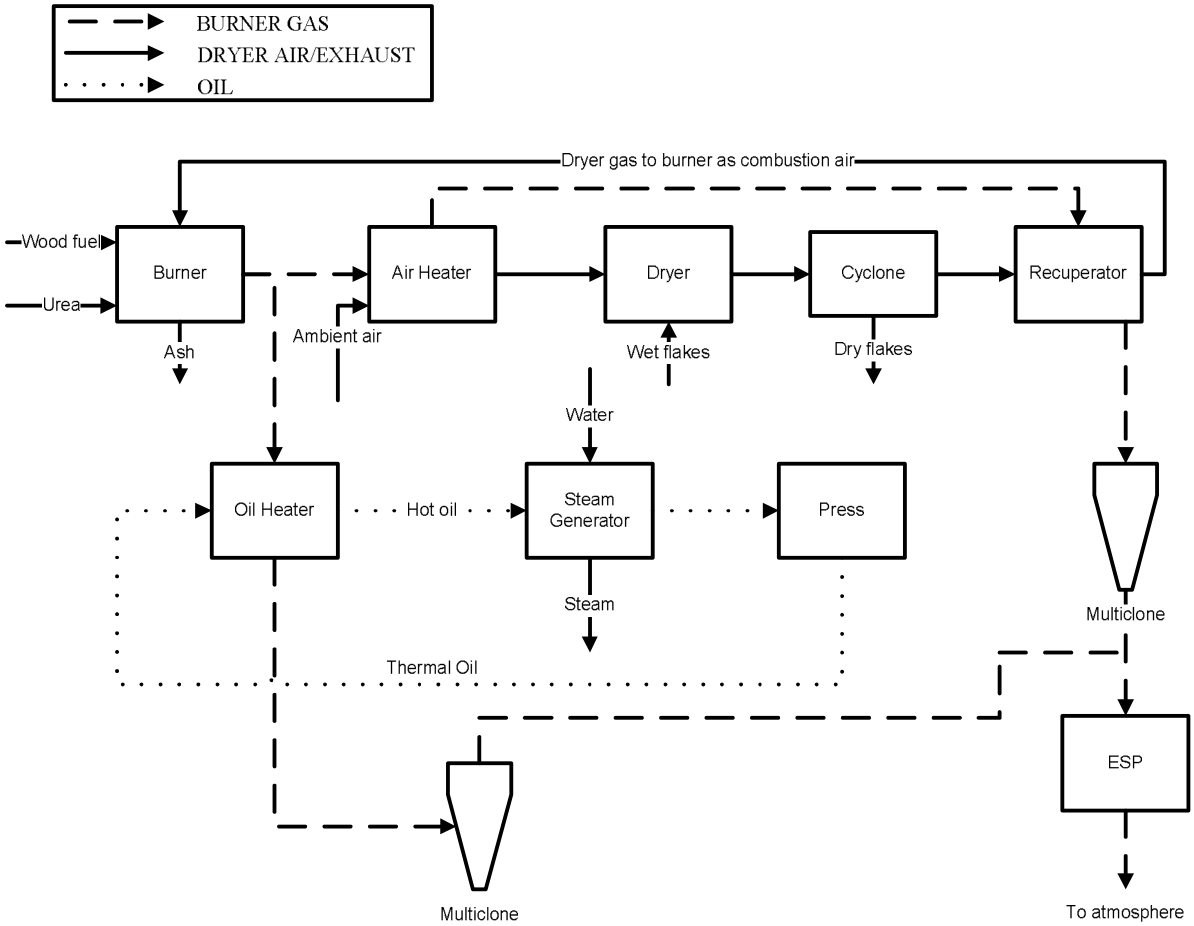

Figure 4-4. Example Diagram of an Energy/Drying System at an OSB Wood Products Facility

Source: Hanks, K. and D. Bullock. 1999. Site Visit—Georgia-Pacific Oriented Strandboard Plant in Brookneal, Virginia (modified figure). Memorandum submitted by MRI to P. Lassiter, U.S. Environmental Protection Agency, Emission Standards Division. March 1, 1999.

The exhaust from the dryers is sent to a multiclone, where dry flakes are recaptured and exhaust gas is sent to the recuperator. The recuperator is another heat exchanger, which uses the cool air exhaust from the air heater to heat the cool air exhaust from the dryer cyclone. The outlet cooled burner exhaust from the recuperator is sent to a multiclone and electrostatic precipitator (ESP) for particulate removal. The cleaned air is vented to the atmosphere. The outlet heated air from the recuperator is recirculated through the burner as combustion air and the process begins again (Hanks and Bullock, 1999).

Callidus CLGS. Figure 4-5 is a simplified flow diagram of a CLGS at a MDF wood products facility. The Callidus CLGS begins with the rotary kiln gasifier. Wood fuel from the MDF process is burned inside the gasifier. Because of the limited amount of air within the gasifier, complete combustion of the wood fuel does not occur, and combustible gases are formed (i.e., the wood fuels are gasified). The combustible gases from the gasifier are fed into the secondary

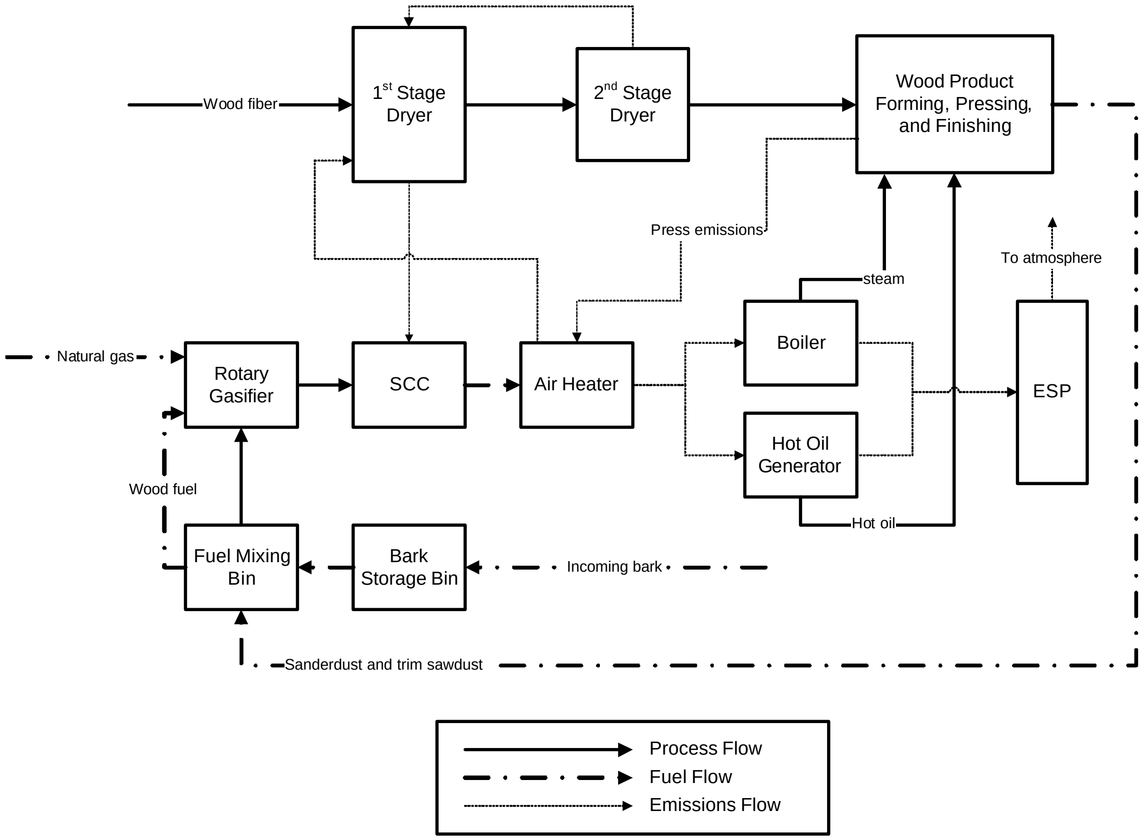

Figure 4-5. Closed-Loop Gasification System at a MDF Wood Products Facility

Source: Icenhour, M. and R. Nicholson. 2002. Trip Report for July 25, 2001 Site Visit to the Del Tin Fiber Medium Density Fiberboard Plant in El Dorado, Arkansas (figure modified). Memorandum submitted by MRI to M. Kissell, U.S. Environmental Protection Agency, Emission Standards Division. April 16, 2002.

combustion chamber (SCC), where they are blended with natural gas (for startup only) and exhaust from the dryers, assuring complete destruction of the unburned organic vapors, fine wood particles, and CO. The exhaust from the SCC is passed through a few heat exchangers within the air heater, which is heated by press exhaust. The heated exhaust air is split between heating the oil used in the MDF press and air for the dryers. The cooled exhaust air flows a dry ESP, where any remaining PM is filtered, and cleaned air is vented to the atmosphere.

4.3.2 Potential Energy, Environmental and Cost Impacts

The number of wood products facilities that use these closed-loop systems is expected to increase as new wood products facilities come on-line and must comply with environmental regulations (also see Section 5.1). These closed-loop systems perform at the same level as an RTO; thus, there are no negative environmental impacts associated with their use. Positive energy and global climate change impacts result from the use of wood fuel to achieve drying and pollution control needs, rather than using a natural gas–fired RTO. Biomass consumption would also be expected to increase because some facilities that install these systems do not generate sufficient quantities of biomass on site. For example, MDF facilities typically start their production process with wood chips rather than whole logs, and therefore, these facilities would not be generating bark on site. Also, the sectors of the wood products industry most likely to use these technologies (i.e., OSB and MDF) are sectors that have shown continued growth and new facility startups, further increasing the demand for waste wood fuels. The initial capital investment required for a closed-loop system is greater than that required for an RTO; however, the higher capital costs are offset by the lower operating costs, especially during periods of higher natural gas prices (Hanks and Bullock, 1999).

4.4 Cogeneration Units at Lumber Mills

Increasing costs for fossil fuels and electricity and new government programs that provide incentives for renewable energy systems have led to an increase in biomass-fueled cogeneration systems at lumber mills. These systems, which generally consist of a wood waste boiler, steam turbine generator, and associated equipment, produce steam for heating the lumber kilns and for generating electricity for in-plant use. These systems can be designed to provide sufficient excess electricity for sale to the national grid. For example, a 2005 installation of a wood waste cogeneration system at a lumber mill in the State of Washington is designed to provide a total of 30 MW of power, 7 MW of which are needed for on-site operations, leaving 23 MW available for sale to the power grid (WA, 2005).

Environmental impacts associated with these cogeneration systems are positive and include lower GHG emissions (by displacing energy produced using fossil fuels), as well as decreases in other pollutants, depending on the specific fossil fuel being displaced. Emissions reductions are greatest when the fossil fuel being displaced is coal. Another positive impact is the decreased quantity of wood waste sent to landfills.

Costs impacts associated with adding biomass-based cogeneration units at lumber kilns are site-specific, but would include the capital costs of the systems (less any financial incentives), future operating cost savings, and income for sale of electricity to the national grid (for systems that generate excess electricity). For example, New Jersey’s Clean Energy Program provides financial incentives (e.g., up to 30% of the eligible system costs for sustainable biomass energy systems greater than 10 kW, based on 2005 rates) to help reduce the initial capital investment required for these systems (NJ, 2005a). One lumber facility that participated in the New Jersey’s Clean Energy Program reported savings of $120,000 per year on natural gas and $75,000 per year in electricity costs. With its new system, this facility is able to meet 50% of its electricity requirements in winter and 100% in the summer. Prior to installation of the cogeneration system (i.e., wood waste boiler, steam turbine generator, and related equipment), natural gas was used to provide heat to the lumber kilns and wood waste generated on site was trucked to a landfill for disposal (NJ, 2005b).

5. Environmental Regulations

5.1 Existing Regulations

The forest products industry is subject to a number of federal, state, and local regulations. Federal regulations currently affecting the forest products industry include the following air, water, and other regulations established under the Clean Air Act, Clean Water Act, and other legislation.

5.1.1 Air Regulations

- National Emission Standards for Hazardous Air Pollutants (NESHAP)—Pulp and Paper Combustion Sources, Pulp and Paper Production, Plywood and Composite Wood Products (PCWP), Paper and Other Web Coating, Wood Building Products Surface Coating, Industrial Boilers (Boiler maximum achievable control technology [MACT])
- National Ambient Air Quality Standards (NAAQS)
- New Source Performance Standards (NSPS)—Kraft Mills, Industrial Boilers, Gas-Fired Turbines, Volatile Organic Liquid Storage Vessels
- Non-Road Diesel Engines and Fuel Rule
- Prevention of Significant Deterioration (PSD)/New Source Review (NSR)
- Regional Haze Rule
- Emissions Trading Rules—Clear Skies Act, Acid Rain Program, NO_x Budget Trading Program, and Clean Air Interstate Rule (CAIR)
- Renewables Portfolio Standards (voluntary)

5.1.2 Water Regulations

- Pulp and Paper Effluent Limitations Guidelines and Standards, Pretreatment Standards, and NSPS
- National Pollutant Discharge Elimination System (NPDES) Related Statutes and Regulations
- Spill Prevention Control and Countermeasure (SPCC) Plans
- Notice of Discharge of Reportable Quantities of Hazardous Substances
- Great Lakes Initiative

5.1.3 *Other Regulations*

- Resource Conservation and Recovery Act (RCRA)
- Emergency Planning and Community Right-to-Know Act (EPCRA)/Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)
- Toxic Substances Control Act (TSCA)
- Endangered Species Act
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
- Occupational Safety and Health Act (OSHA)

Of these regulations, the Cluster Rules (i.e., Pulp and Paper Combustion Sources NESHAP; Pulp and Paper Production NESHAP; and Pulp and Paper Effluent Limitations Guidelines and Standards, Pretreatment Standards, and NSPS), PCWP NESHAP, Industrial Boilers NESHAP (Boiler MACT) and NSPS, and NAAQS are expected to have the most direct impact on the forest products industry (EPA, 2001b; AF&PA, 2005b; EIA, 2005b).

5.1.4 *Effects of Recent Environmental Regulations on Biomass Consumption*

As the industry has come under more stringent environmental regulations, capital expenditures have increased to ensure air and water quality, recover waste products, use recycled feedstocks, and reduce energy use, which may impact biomass usage.

The recently promulgated (2005) Boiler MACT rule is expected to have only a modest impact on biomass usage. The rule neither favors nor penalizes biomass as a fuel. The rule's health-based compliance option for manganese will help biomass boilers avoid installation of additional control equipment that could have caused some fuel switching. On the other side, the emissions averaging risk approach for chlorine gas will allow coal to continue to be an important part of the fuel mix at pulp and paper operations. Although the Boiler MACT rule establishes limits for mercury emissions, mills are not expected to comply by switching from coal to wood biomass. Biomass boilers exist at both pulp mills and wood product facilities, and, to the extent that wood products facilities rely more heavily on biomass for their boilers, it may have a disproportionate impact on that industry sector (AF&PA, 2005b).

The 2005 PCWP MACT rule, which was also recently promulgated, is not expected to significantly impact biomass usage. The rule covers wood-fired burners and other combustion units whose emissions directly exhaust through wood particle/fiber dryers used in the manufacture of PCWP. Gaseous emissions from most of these dryers and other PCWP process units such as presses are required to be reduced, and the most common method for reducing these emissions is to combust these gases in RTOs that are fueled by natural gas (EPA, 2004).

These RTOs simply add to the overall fuel consumption at the facility rather than displacing biomass fuel. However, as more PCWP facilities come online with closed-loop biomass energy systems rather than RTOs, biomass fuel consumption could potentially increase, as discussed in Section 4.3.

The upcoming Industrial Boilers NSPS could negatively affect biomass boiler usage. A modification to a boiler might trigger very stringent PM limits (tighter than Boiler MACT) that would be hard for existing biomass boilers to meet without significant expense (AF&PA, 2005b).

In the longer term, the $PM_{2.5}$ NAAQS may have an impact on biomass boilers if EPA shifts away from NO_x and SO_2 controls to organic carbon, which comes from industrial biomass boilers. At this point, most discussion centers around wood stoves, fireplaces, charbroilers, and forest fires rather than industrial boilers, which have a high combustion efficiency and generally good particulate control. However, as standards get more stringent, even marginally contributing sources could come under scrutiny (AF&PA, 2005b).

Besides NAAQS, Regional Haze Rule, and Boiler MACT, EPA is also considering both regulatory and voluntary approaches to reducing emissions from industrial boilers as a class, as well boilers within the pulp and paper sector. According to an industry source [AF&PA], the focus is expected to be on coal-fired boilers rather than biomass systems. However, if coal use decreases or gets more expensive, then biomass may pick up some of the energy needs (AF&PA, 2005b). Coal use may also be affected by future regulations on emissions of mercury.

RPS that recognize biomass and provide incentives may increase the use of biomass. In addition, because burning biomass is carbon neutral and does not contribute to emissions of CO_2 (the primary GHG), there is concern in the forest products industry that it may trigger increased demand for and use of biomass. There are no mandatory controls on GHG emissions in the United States, but for companies taking voluntary action, biomass may be an attractive fuel source (AF&PA, 2005b).

5.2 Policy Proposals

A number of policy proposals under consideration may have significant direct and indirect impacts on the forest products industry. These environmental policies are generally related to GHG reduction efforts and have implications for both the biomass and fossil fuel energy consumption of the industry. As noted by AF&PA (2005), biomass fuels are considered carbon neutral and do not contribute to overall emissions of CO_2 While there are currently only limited mandatory controls on GHG emissions in the United States (discussed below), for companies taking voluntary actions, biomass may be an attractive fuel source. In addition, potential future environmental policies may alter the relative prices of biomass energy versus fossil fuels and might even affect overall availability of biomass. These effects could be the result of direct regulations or spillover effects from policies in other industries, such as electricity generation.

One such policy that has gained in popularity in recent years is RPS for electric utilities. Although there is no national standard, 21 states have set standards specifying minimum generation levels from renewable energy sources, generally through these RPS policies. Figure 5-1 illustrates these mandated RPS levels for different states. In 2004, across the United States, renewable generation (excluding hydroelectricity) by electric utilities represented around 1.5% of total generation (EIA, 2005d). With more than 40% of states already specifying some sort of RPS, this renewable generation number could increase significantly and result in higher biomass prices and reduced availability. AF&PA (2005) has expressed concerns regarding these types of issues.

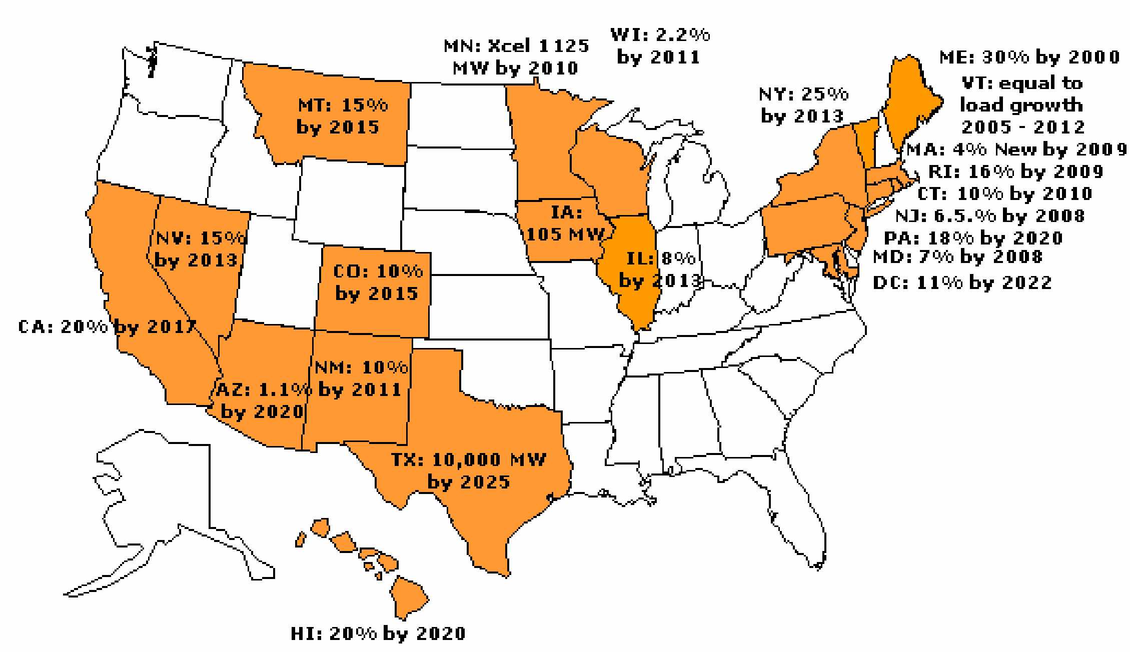

Figure 5-1. State-Level Renewable Portfolio Standards

Source: Pew Center on Global Climate Change (Pew Center). 2005b. States with Renewable Portfolio Standards. Available at: http://www.pewclimate.org/what_s_being_done/in_the_states/rps.cfm.

National-level standards have been also proposed, if not implemented. For example, in 2003, Senator Bingham of the Senate Committee on Energy and Natural Resources requested that EIA analyze a proposal specifying a RPS with an incremental increase in renewables of 10% by 2020 (EIA, 2003). EIA estimated that the policy would result in an additional 15 billion kWh of electricity generation from biomass cofiring in 2020, roughly equal to 150 trillion Btu of biomass.[4] No substantial additional dedicated biomass was expected as the result of the RPS, but baseline biomass generated was forecasted to rise from 1.7 billion kWh in 2001 to 61.6 billion kWh in 2020. Little effect on electricity prices was estimated (+0.4%) and natural gas prices were expected to drop by 1.5%, which could reduce production costs in the forest products industry and help offset any potential increases in the costs of biomass purchases (no biomass prices were presented in the analysis). It should be noted that the EIA analysis estimates that most of the RPS requirements are met through additional wind generation, not biomass generation.

Another type of state-level electricity policy that may conceivably affect the forest products industry through changes in electricity markets and fossil fuel or biomass prices is green marketing/pricing. Currently, customers in 34 states can opt for green marketing/pricing, where they agree to pay more for electricity in order to support renewable generation (Figure 5-2). Although it would be difficult to quantify these effects, as with RPS and to the extent that the policy encourages additional biomass use by electric utilities, it has the potential to affect the forest products industry.

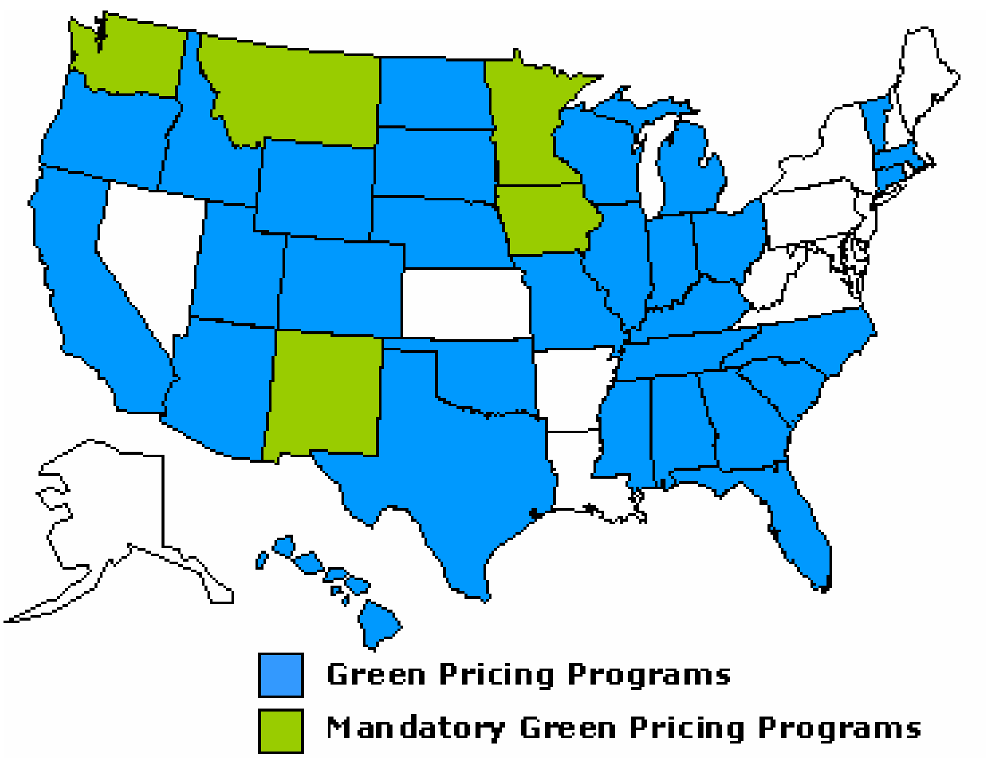

Figure 5-2. State-Level Green Pricing Programs

Source: Pew Center on Global Climate Change (Pew Center). 2005a. States with Green Pricing Programs. Available at: http://www.pewclimate.org/what_s_being_done/in_the_states/west_coast_map.cfm.

[4] Based on an assumed heat rate of 10,000 Btu per kWh in the biomass cofiring.

Numerous strategies have been proposed specifically to reduce GHG emissions. In 2005, the Kyoto Protocol, which reduces GHG emissions below 1990 levels for most participating countries, entered into force among Annex I parties (i.e., industrialized countries) that signed the agreement. The United States has not signed this accord, however, a variety of national-, regional-, and state-level proposals for reducing GHG emissions are being circulated:

- *Climate VISION.* The forest products industry is supporting U.S. GHG reductions through the Climate VISION program sponsored by the U.S. Department of Energy (CV, 2001). The program is based on President Bush's proposal in 2002 to reduce GHG emissions intensity by 18% over the subsequent 10 years.
- *Regional Greenhouse Gas Initiative (RGGI).* On December 20, 2005, seven states in the northeast announced an agreement to implement RGGI, which limits CO_2 emissions from electric utilities to current levels from 2009 to the start of 2015, followed by a 10% reduction in emissions by 2019 (RGGI, 2005). Safety values limit the cost of a permit to emit a ton of CO_2 to between $7 and $10.
- Additional regional proposals. There are also a variety of other regional proposals under consideration in more than half of the United States (Pew Center, 2005c).
- *Climate Stewardship Act of 2003.* The most comprehensive national proposal under recent consideration is the McCain-Lieberman Climate Stewardship Act. The act would establish a target for U.S. GHG emissions equal to those in the year 2000, beginning in 2010. There are exemptions for some sectors and provisions for allowances.

Impacts of the Climate Stewardship Act on energy prices and consumption patterns have been analyzed by EIA (2004). The study finds that GHG permit prices start at around $15 per ton of CO_2 in 2010, rising to around $35 per ton by 2020. This leads to an increase for the industrial sector (including the forest products industry) in electricity prices of around 25%, natural gas prices of 40%, and coal prices of over 200% by 2020. These energy price increases cause biomass generation by electric utilities to increase to close to 190 billion kWh. However, renewable energy consumption in the industrial sector is expected to remain essentially unchanged as any increases in biomass prices, along with diversion to electric utilities, are offset by the increases in fossil fuel prices and thus greater incentives to expand biomass supplies.

6. Additional Considerations

6.1 Process Equipment Replacement Schedules

As shown in Figures 6-1 and 6-2, approximately 50% of existing chemical recovery furnaces and wood-fired boilers were originally installed more than 30 years ago. Although there have been incremental upgrades, repairs, and other modifications made to these furnaces and boilers since they were originally installed, many of these units will need to be replaced over the next 5 to 20 years, which provides a window of opportunity for these mills to consider converting to black liquor and/or wood gasification systems for all or part of their process.

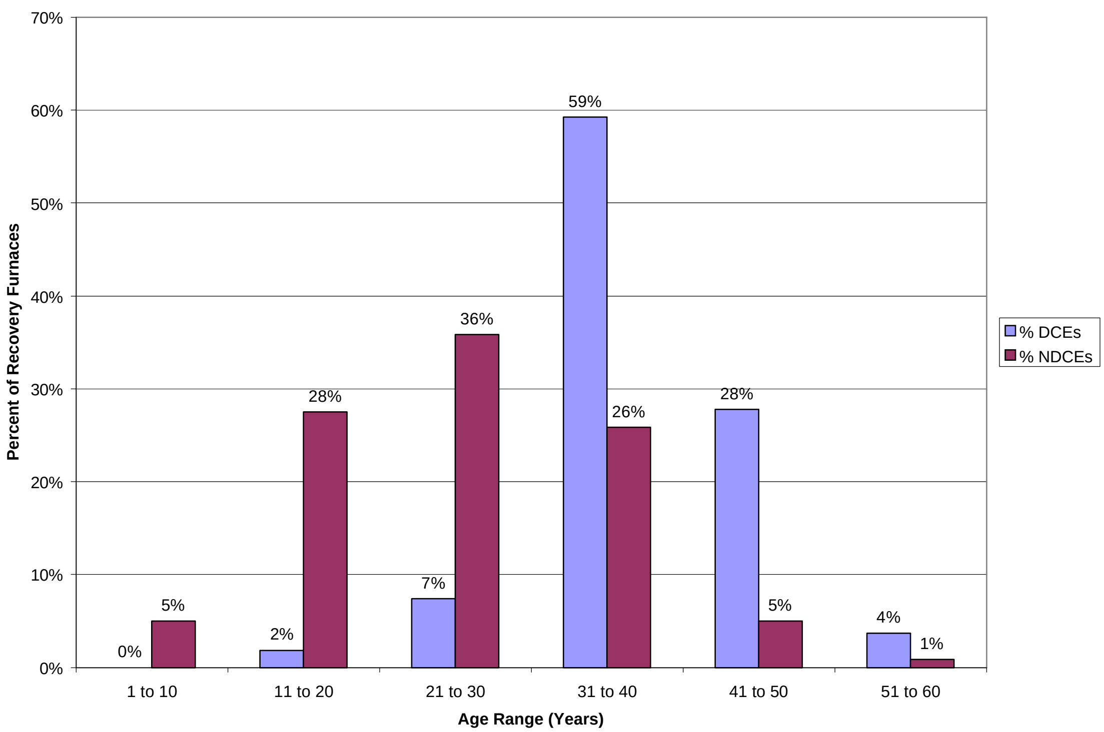

Figure 6-1. Age Distribution of Recovery Furnaces at Kraft Pulp Mills

Sources: RTI International (RTI). 2005. Pulp & Paper Recovery Furnace Database; and Black Liquor Recovery Boiler Advisory Committee (BLRBAC). 2005. BLRBAC Database. Available at: http://www.blrbac.org. Accessed December 21, 2005.

Since the 1980s, growth in the pulp and paper industry has been achieved by expanding the capacity of existing mills rather than starting up new mills, due in part to the difficulties in obtaining environmental permits for new "greenfield" pulp mills. Therefore, there is a continuous cycle of equipment replacement whereby older, less efficient equipment is replaced with newer, larger, and more efficient equipment. For example, recovery furnaces installed today are much larger than furnaces installed 30 years ago, such that one new recovery furnace can often replace two older existing recovery furnaces. Also, many of the older pulp mills will have

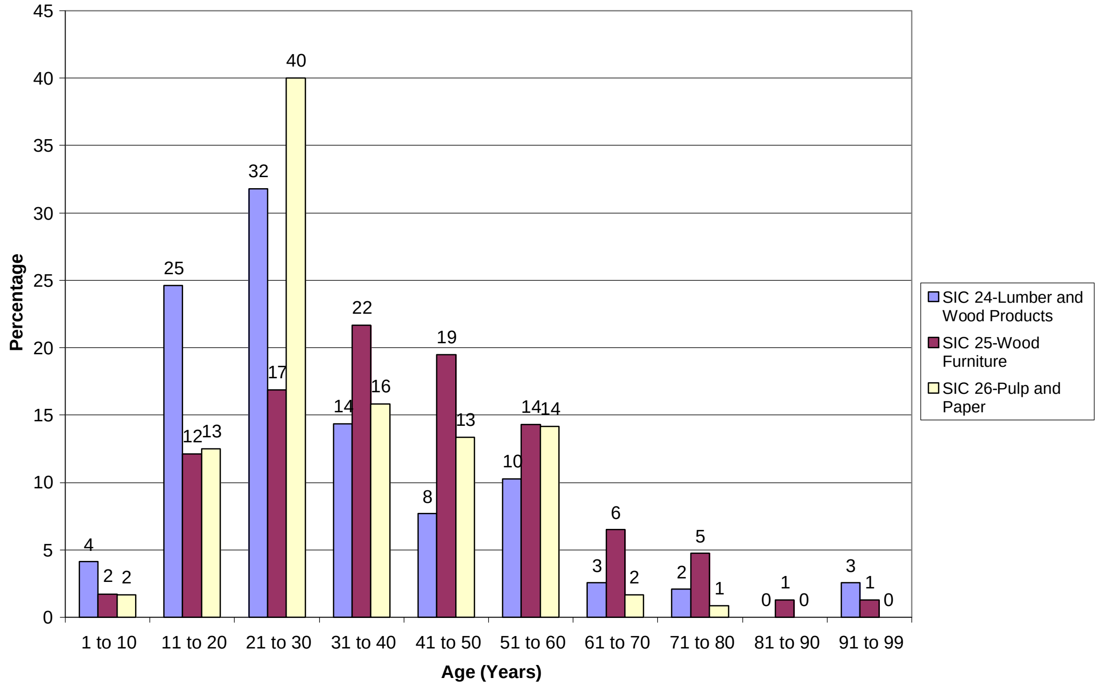

Figure 6-2. Age Distribution of Wood-Fired Boilers at Forest Products Facilities

Sources: U.S. Environmental Protection Agency (EPA). 1997. Industrial Boilers Database; and U.S. Environmental Protection Agency (EPA). 1999. National Emissions Inventory Database.

relatively new boilers operating side-by-side with much older boilers. In these cases, at least initially, mills may choose to replace only the older boilers/furnaces with gasification systems. Newer mills may wait longer or only implement gasification as a way of increasing capacity until the economics make it favorable for them to abandon their relatively new equipment for gasification units. In the near-term, replacement of conventional wood-fired boilers with fluidized bed boilers is expected to continue, as discussed in Section 4.2.

6.2 Fuel Prices and Availability

Technology adoption, and hence biomass energy consumption, will depend on technology costs and efficiencies and on prices of fossil fuels (and purchased biomass, if used). The availability, or perceived availability, of biomass may also alter facilities' decisions. In the short run, because fossil fuels are used to supplement self-generated biomass and/or generate electricity, companies evaluate costs of alternative energy sources when choosing a fuel mix. Over the longer run, technologies can be changed or improved to increase biomass energy utilization.

One possible short-term determinant affecting biomass costs and related fossil fuel use is the price of pulpwood used by the paper industry. Figure 6-3 illustrates how some of these prices have varied over time (Howard, 2003). Softwood prices are generally higher than hardwoods,

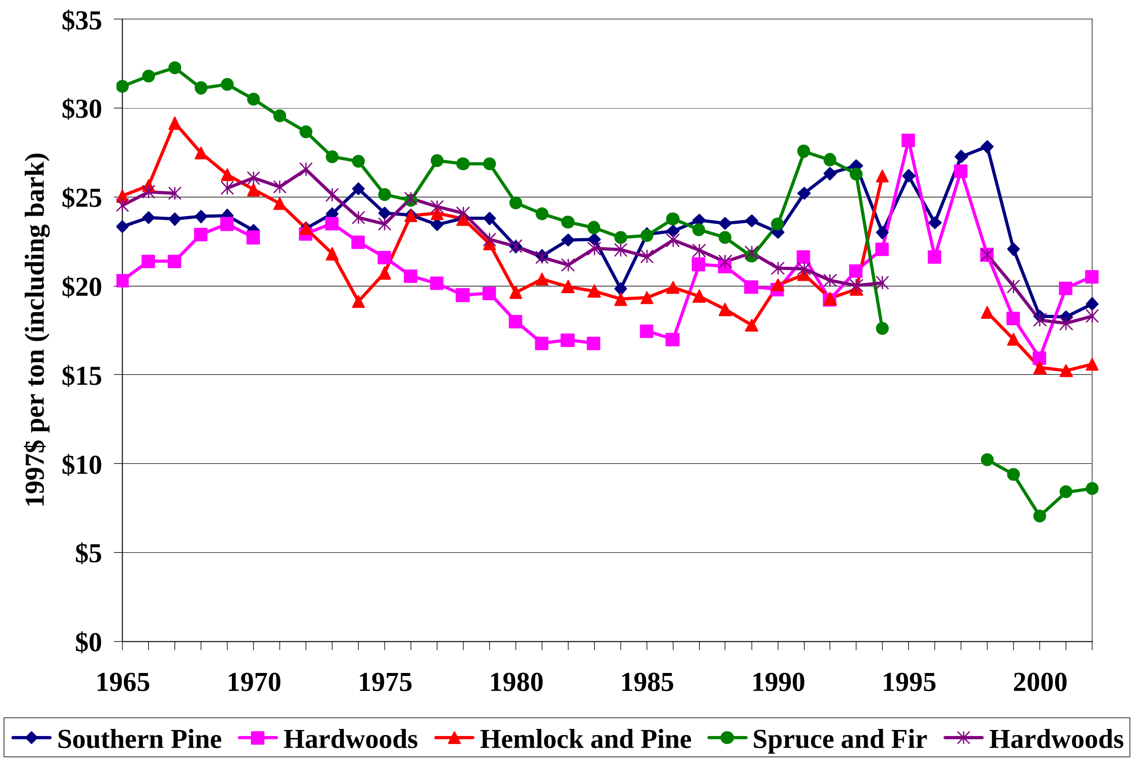

Figure 6-3. Delivered Pulpwood Prices (1965–2002)

Note: Missing prices are not available. Converted from cords to tons at 2.65 green tons per cord.

Source: Howard, J.L. 2003. U.S. Timber Production, Trade, Consumption, and Price Statistics 1965–2002. United States Department of Agriculture Forest Service, Forest Products Laboratory, Research Paper FPL-RP-615. Available at: http://www.fpl.fs.fed.us/documnts/fplrp/fplrp615/fplrp615.pdf.

however, both price trends have demonstrated a fair amount of volatility over the last decade. According to Howard (2003), this volatility has been due to declining capacity and restructuring in the pulp and paper industry in recent years, leading to a smaller manufacturing base and declining demand.

Figure 6-4 compares biomass energy consumption in the industrial sector (most wood and waste used by this sector is consumed in the forest products industry [see Section 2.3]) to biomass and fossil fuel prices (in nominal terms). Unlike pulpwood prices, the price of wood/waste for energy has generally increased slightly over the last 10 years, even as overall biomass energy consumption has fallen. Given that most biomass is self-generated rather than purchased, biomass consumption is more directly correlated with overall pulp and paper production than with wood/waste prices. There is some relationship between biomass use and natural gas prices through 1996 and 1997, but the relationship declined in significance afterwards as the industry experienced a broad change in production in the late 1990s and into the 21st century.

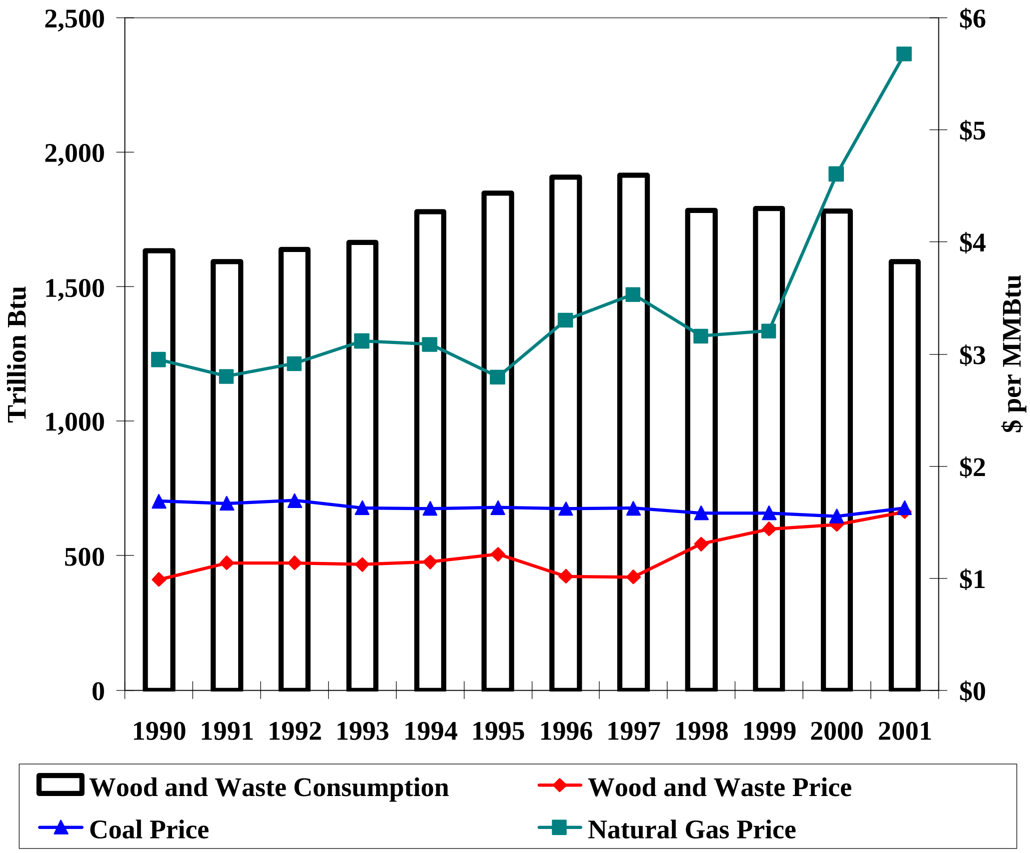

Figure 6-4. Industrial Sector's Biomass Energy Consumption and Related Fuel Prices

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2005d. State Energy Consumption, Price, and Expenditure Estimates. Available at: http://www.eia.doe.gov/emeu/states/main_us.html.

Although there is no definitive relationship in the historical data between biomass consumption and fossil fuel prices (most likely because of a lack of data on biomass purchases, as opposed to total biomass use in the figure that includes self-generated supplies), according to AF&PA (2005) and Weyerhaeuser (2005), the most important factor affecting biomass use as a fuel is the price of fossil fuel substitutes. They indicated that, if fossil fuel prices reach high enough levels, there are strong incentives to increase biomass use in both the short- and long-term, which is true for electric utilities, as well as the forest products industry. They also noted that a prolonged curtailment of fossil fuel supplies, which occurred recently with natural gas at some facilities, can also increase incentives to use biomass.

There is some concern in the industry that forest products facilities purchasing biomass from outside sources can be vulnerable to supply changes and disruptions. For example, if a pulp and paper mill purchases most of its wood fuel from a nearby sawmill and the sawmill shuts down, then the pulp and paper mill may have to rely more heavily on lower-quality wood residues that are generated on site (e.g., wet bark). Such a change can result in an overall decrease in the amount of biomass burned by the pulp and paper mill and a corresponding increase in fossil fuel consumption to maintain the same rate of steam generation. The mill may also have to look at other nonbiomass fuel sources such as tire-derived fuel to make up for the loss of the higher-quality wood fuel.

Another issue that affects availability of biomass fuel is competition from wood products facilities that can use the biomass in their manufacturing process. In some cases, this competition can take place within a given wood products facility. For example, a wood products facility in the Southeast noted that they could rely solely on bark and wood residues generated on site for fuel for their biomass burner; however, the facility elects to sell their wood residues (e.g., sander dust, fines, board trim) to other wood products facilities at a rate of about $16 to $20 per ton (values in 1999$) and then purchase additional bark for fuel at about $8 to $10 per ton (Georgia-Pacific, 1999). Thus, the higher-quality wood residues are considered too valuable to use as fuel. Another factor in this facility's decision to sell the wood residues rather than burn them for fuel is that the facility would have to store wood residues generated during seasonal production surges to cover the yearly demand.

6.3 Other Issues

Other issues that affect the use of biomass as a fuel include the cost and availability of industrial landfills and the ability of forest products facilities to find beneficial uses for wood waste and pulp mill WWT sludge. In 1995, the median landfill at a pulp and paper mill covered 30 acres, was 13 years old with 10 years of life remaining, and was two-thirds full (NCASI, 1999). The median reported cost of using these landfills was $10 per cubic yard (NCASI, 1999). As discussed in Section 3.1.2, pulp and paper mills have significantly reduced the percentage of wood waste and WWT sludge that is landfilled in favor of beneficial uses such as energy generation. As shown in Figure 6-5, almost half of the sludge generated at pulp and paper mills is diverted to beneficial uses, including burning for energy recovery, recycling to the process (because sludge contains a significant amount of wood fiber), and land application (NCASI, 1999). As noted in Section 3.1.2, the percentage of WWT sludge used as fuel has more than doubled since 1979 (NCASI, 1999). In some cases, other beneficial uses may divert the sludge from energy production, as well as from the landfill, although the trend toward increased biomass fuel consumption is expected to continue.

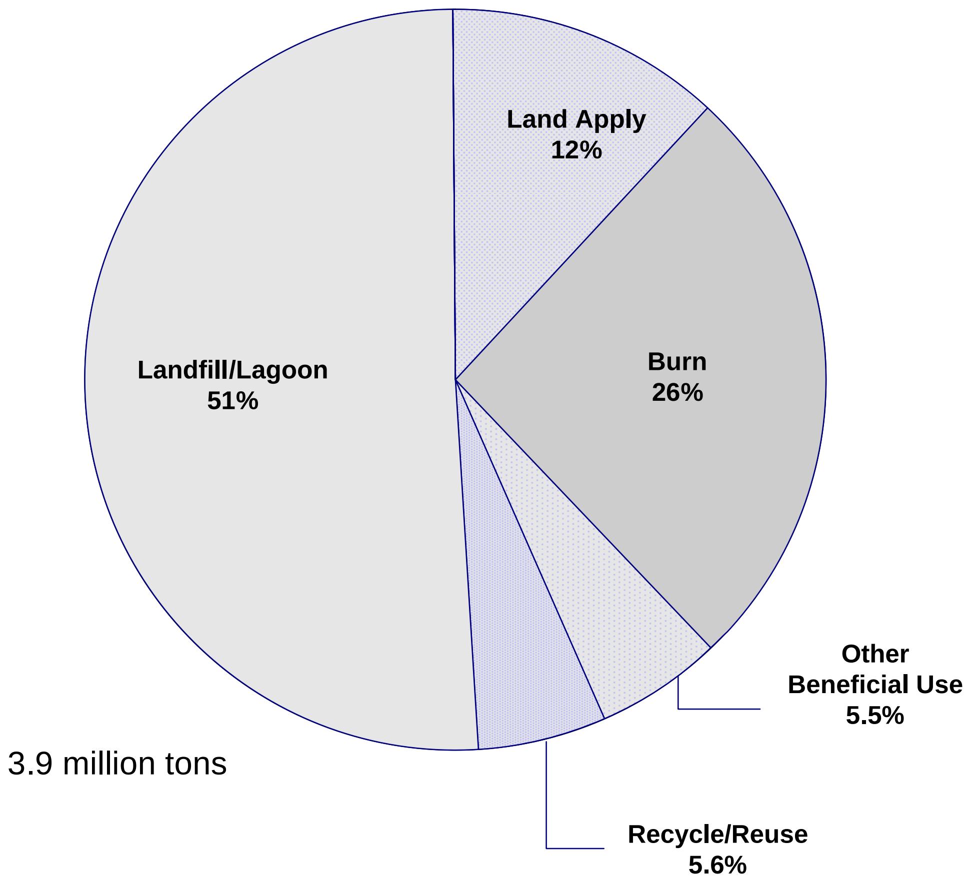

Figure 6-5. Final Disposition Management Methods for Wastewater Treatment Residuals

7. Future Use of Biomass Energy

This section summarizes the information discussed in previous sections on how different types of biomass energy consumption may be affected by industry and economic trends. While it is difficult to predict exactly how the mix of technological, economic, and policy factors will combine to affect future biomass consumption in the forest products industry, qualitative directional indicators are assigned to the various points, as shown in Table 7-1.

Successful implementation of BLG and the forest products biorefinery concept could transform the pulp and paper industry; however, there are still technical barriers that must be overcome before these technologies can significantly penetrate the kraft pulping sector. Research aimed at removing these barriers is ongoing, but large-scale implementation of the biorefinery concept at a kraft pulp mill is not be expected to occur until after 2010. Although foreign competition continues to be a concern for the U.S. pulp and paper industry, the volatility associated with pulp mill closures and company mergers over the last ten years appears to have stabilized, and production of black liquor at kraft pulp mills is expected to remain steady for the next five years.

The forest products industry also continues to conduct research in other areas of the pulp and paper manufacturing process that are expected to result in incremental energy savings. However, successful implementation of BLG, along with other factors such as the cost and availability of fossil fuels, are expected to have more direct impacts on biomass fuel consumption than any incremental reductions in process energy requirements.

At pulp and paper mills, the trend towards increasing numbers of fluidized bed biomass is expected to continue in the future, even as research proceeds on other technologies such as wood gasification. Fluidized bed technology will increase consumption of biomass in the form of waste wood and sludge as mills improve their utilization of self-generated fuels. Implementation of wood gasification is expected to trail BLG, encouraging the move towards fluidized bed boilers. Regardless of the penetration of either technology, both favor the use of waste wood and sludge as fuel, implying that biomass consumption will increase.

At wood products facilities, biomass fuel consumption is also expected to increase due the continued growth in industries using wood residues as fuel for wood drying (e.g., oriented strandboard and medium density fiberboard manufacturing facilities) and expansions in new facilities with combined dryer/energy systems (e.g., closed-loop gasification systems). The recent trend toward biomass-fueled co-generation systems at lumber manufacturing facilities is also expected to continue as additional government programs provide incentives for renewable energy systems. The potential also exists for new types of policies related to climate-change mitigation to impact biomass fuel consumption.

One factor that could negatively impact installation of new biomass boilers at pulp and paper mills is a drop in natural gas prices, although such a drop is not anticipated. Because the capital cost of a natural gas boiler is less than the cost of a conventional biomass boiler and significantly less than the cost of a fluidized-bed boiler, pulp and paper mills tend to install natural gas boilers rather than biomass boilers during periods when natural gas prices are relatively low.

In summary, over the next 5 years, consumption of black liquor is expected to remain steady, and consumption of wood residuals and sludge is expected to increase slightly. The outlook for the next 10 years depends significantly on the success or failure of black liquor gasification to penetrate the kraft pulping sector and future government programs that provide incentives for renewable energy. Successful implementation of BLG would not only greatly increase the amount of energy that could be extracted from black liquor, but would also significantly improve the economic condition of the kraft pulping sector. Energy production from wood-based biomass fuel consumption is not technology-limited and will continue to increase regardless of the future of BLG. Full implementation of the forest products biorefinery concept includes wood gasification, and therefore, if the concept is fully realized, this would further increase future wood biomass energy production.

Table 7-1. Expected Changes in Biomass Energy Consumption and Contributing Factors

Type of Biomass	Quantity Consumed In 2000[a] (trillion Btu, unless noted)	Expected Directional Changes through 2010: Quantity of Biomass Fuel Generated	Expected Directional Changes through 2010: Quantity of Biomass Fuel Consumed	Primary Factors Contributing to Increased Consumption	Primary Factors Contributing to Decreased Consumption	Comments
Spent (black) liquor	895	Flat	Flat	Successful full-scale implementation of BLG at kraft pulp mill	Foreign competition leading to mill closures and production curtailments	(1) BLG not likely to significantly penetrate market until after 2010 and even then may be slow (2) Economic conditions at chemical pulp mills appear to have stabilized, no additional mills shutdowns or production curtailments expected in next 5 years
Wood residuals	327	Increase	Increase	(1) Increases in fossil fuel prices (2) Disruptions in availability of fossil fuels (3) Financial incentives for using renewable energy fuels (4) Successful full-scale implementation of wood gasification at pulp mill	(1) Lower fossil fuel prices, especially natural gas (2) Competition for biomass fuel (e.g., from utilities)	(1) In the short term (e.g., next 5 years), biomass fuel consumption is expected to increase somewhat independently of fossil fuel prices, as more fluidized-bed boilers are installed at pulp mills, more cogeneration facilities are built at lumber mills, and new wood products facilities invest in closed-loop drying and energy systems (2) In the longer term (after 2010), successful implementation of wood gasification energy systems at pulp and paper mills should further increase biomass fuel consumption; however, the development of wood gasification systems could be slowed if fossil fuel prices drop significantly and/or if funding for its development at pulp and paper mills is diminished
Pulp and paper WWT sludge	3.7 million BTU[b,c]	Increase	Increase	(1) Increases in fossil fuel prices (2) Disruptions in availability of fossil fuels (3) Increased used of recycled fiber in papermaking (4) Decreasing landfill space; increasing landfill costs	(1) Lower fossil fuel prices, especially natural gas (2) Internal and external competition for sludge (e.g., recycling of fiber to process; sale to of sludge to end users such as asphalt roofing manufacturers)	(1) The use of recycled fiber is expected to continue, both at integrated mills and at mills that produce 100% recycled paper (2) Increased use of sludge as fuel is expected to continue even as more mills find other uses for the sludge

[a] *Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program (EERE). 2005. Energy and Environmental Profile of the U.S. Pulp and Paper Industry. Prepared by Energetics Corporation. Available at: http://www.eere.doe.gov/industry/forest/pdfs/pulppaper_profile.pdf*

.[b] *Source for tons of sludge: National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI). 1999. "Solid Waste Management Practices in the U.S. Paper Industry—1995." Technical Bulletin No. 793. Research Triangle Park, NC: NCASI. September 1999.*

[c] *Source for sludge BTU value: Charlson, Steve. 1999. Bubbling Fluidized Bed Installation Capitalizes on Sludge. Presented at 1999 TAPPI Engineering Conference. Anaheim, CA. September 12-16, 1999.*

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Appendix A: Acronyms and Abbreviations

AF&PA: American Forest and Paper Association
bbf: billion board feet
bf: board feet
BGCC: biomass gasification combined cycle
BLG: black liquor gasification
BLGCC: black liquor gasification combined cycle
BLRBC: Black Liquor Recovery Boiler Advisory Committee
Btu: British thermal units
CAIR: Clean Air Interstate Rule
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act
CLGS: closed-loop gasification system
CO: carbon monoxide
CO_2: carbon dioxide
DCE: direct contact evaporator
DETOX: dryer energy and thermal oxidation
DME: dimethylether
US DOE: U.S. Department of Energy
EERE: Office of Energy Efficiency and Renewable Energy
EIA: Energy Information Administration
EPCRA: Emergency Planning and Community Right-to-Know
ESP: electrostatic precipitator
FERCO: Fossil Energy Research Corporation
FIFRA: Federal Insecticide, Fungicide, and Rodenticide Act
F-T: Fischer-Tropsch
ft^3: cubic feet
GDP: gross domestic product
GHG: greenhouse gas
G-P: Georgia-Pacific
H_2S: hydrogen sulfide
HAP: hazardous air pollutants
IFPB: Integrated Forest Products Biorefinery
kWh: kilowatt-hours
LPG: liquefied petroleum gas
MACT: maximum achievable control technology
MDF: medium density fiberboard
MMBtu: million British thermal units
MRI: Midwest Research Institute
MTCI: Manufacturing and Technology Conversion International, Inc.
MW: megawatt
Na_2CO_3: sodium carbonate
Na_2S: sodium sulfide
NAAQS: National Ambient Air Quality Standards
NAICS: North American Industrial Classification System
NaOH: sodium hydroxide

NCASI: National Council of the Paper Industry for Air and Stream Improvement, Inc.
NDCE: non-direct contact evaporator
NESHAP: National Emission Standards for Hazardous Air Pollutants
NO_X: nitrogen oxides
NPDES: National Pollutant Discharge Elimination System
NSPS: New Source Performance Standards
NSR: New Source Review
OSB: oriented strandboard
OSHA: Occupational Safety and Health Act
PB: particleboard
PCWP: Plywood and Composite Wood Products
PM: particulate matter
PSD: Prevention of Significant Deterioration
PM: Resource Conservation and Recovery Act
RGGI: Regional Greenhouse Gas Initiative
RPS: renewable portfolio standards
RTO: regenerative thermal oxidizer
SCC: secondary combustion chamber
SDT: smelt dissolving tank
SO_2: sulfur dioxide
SPCC: Spill Prevention Control and Countermeasure
TAPPI: Technical Association of the Pulp and Paper Industry
TRS: total reduced sulfur
BEA: U.S. Bureau of Economic Analysis
BLS: U.S. Bureau of Labor and Statistics
USCB: U.S. Census Bureau
USDA: U.S. Department of Agriculture
EPA: U.S. Environmental Protection Agency
ITC: U.S. International Trade Commission
VISION: Voluntary Innovative Sector Initiatives: Opportunities Now
VOC: volatile organic compounds
WWT: wastewater treatment